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The Effects of Latent Trait-Anxiety on Attentional Processing: An ERP Investigation

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Abstract

The aim of the present dissertation was to investigate whether the operation of selective attention differs in people according to variation in latent trait-anxiety in conditions that were ostensibly absent of emotional valence. Repressors and high trait-anxious individuals appear to differ in the strategic operations undertaken to conduct these processes. Repressors show a tendency to attenuate and dismiss potentially threatening information, whereas high trait-anxious individuals show a tendency for amplification and focus. Two studies have reported findings of retarded attentional disengagement by high trait-anxious individuals in the absence of perceptible threat (i.e., Derakshan, Smyth & Eysenck, 2009; Derryberry & Reed, 2002). This suggests that the underlying strategic processes characteristic of high trait-anxiety operate independently of ostensible threat. To date, the proposition that this may also be the case with repressive coping style has not been investigated.

This current investigation comprised three studies, each of which employed performance measures of response time and response accuracy. In addition, event-related potentials (ERPs) were employed as an index of subtle differences in the allocation of attentional resources. Participants were females aged between 17 and 34 years whom had never been formally diagnosed as having an anxiety disorder. The experimental paradigms employed with the three studies were selected for their ability to allow observation of component processes of selective attention. These were based on the mechanisms of disengagement, shifting and engagement described by Posner and Petersen (1990), which remains the leading model of the mechanisms of selective attention (Yiend, 2010).

The first study employed a Stroop-interference experiment to investigate the inhibition of attention as a function of the disengagement sub-component of selective attention. The second study comprised a local-global Stroop-type interference paradigm embedded within a task-switching methodology toward investigating the degrees of operational flexibility possessed by the experimental groups on the subcomponents of selective attention. The final study was conducted to both investigate the prospect that

repressors may possess a characteristic bias for enhanced attention to the discrete stimuli, and elucidate how low trait-anxiety and repressor groups compare on later-stage attentional processing. This comprised a combination of single-task and dual-task paradigms.

Whereas the results of the final study were largely unremarkable, the convergent evidence from the Stroop-interference and task-switching studies offered reasonable support for the two-stage model of attentional processing in repression proposed in Vigilance-Avoidance Theory (Derakshan et al., 2007). Taken together, the findings of the present dissertation support the propositions that repressors represent a distinct sub-group of high trait-anxious people, and that the characteristic attentional processing styles of both of these groups operate independently of ostensible threat.

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Chapter 1: Thesis Overview

Different personality styles entail different cognitive processing styles, and there is strong evidence of variation in the psychological management of information interpretable as signifying potential threat. It is well-established that individuals with high levels of trait-anxiety show an attentional bias for threatening stimuli or events (Eysenck & Byrne, 1992; Fox, Russo, & Dutton, 2002; Mogg & Bradley, 1998; Wilson & MacLeod, 2003). Given the detrimental effect of threat-perception on processing efficiency in high trait-anxiety, the development of functional compensatory strategies would appear adaptive. One such strategy is repression. Individuals employing a repressive coping style report low trait-anxiety, but show high-anxious reactivity on psychophysiological indices.

Repressors and high trait-anxious individuals appear to differ in the strategic operations undertaken to conduct these processes. Repressors show a tendency to attenuate and dismiss potentially threatening information, whereas high trait-anxious individuals show a tendency for amplification and focus. Two studies have reported findings of retarded attentional disengagement by high trait-anxious individuals in the absence of perceptible threat (i.e., Derakshan, Smyth & Eysenck, 2009; Derryberry & Reed, 2002). This suggests that the underlying strategic processes characteristic of high trait-anxiety operate independent of ostensible threat. To date, the proposition that this may also be the case with repressive coping style has not been investigated. Hence, the aim of the present dissertation was to investigate whether the operation of selective attention differs in people classifiable as either low trait-anxious, medium trait-anxious, high trait-anxious, or repressors, in an emotionally neutral context.

The present introductory chapter (Chapter 1) provides an overview of the structure of the present dissertation and is followed by a chapter reviewing the personality constructs of interest to the current thesis (Chapter 2). This begins with a discussion concerning the definition of personality and description of a selection of the more popular theories toward some representation of the gamut. The concept of personality traits is then introduced, which leads to the discussion of trait anxiety and repressive coping style. The concept of attention is discussed in Chapter 3. The definition of

attention is addressed prior to the presentation of the major theoretical developments relating to selective attention. This leads to the introduction and discussion of the component processes of selective attention proposed by Posner and Petersen (1990); these being, disengagement, shifting and engagement. The chapter concludes with discussion of the concept of attentional control.

As the present thesis is concerned with event-related brain potentials (ERPs) as indices of cognitive resource allocation to attentional processing, Chapter 4 is dedicated to discussion of ERPs. This begins with a general introduction to ERPs, followed by introduction and discussion of the correlates of each of the components of interest; these being N1, P2, N2 and P3. Theories and evidence relating to selective attention processes in anxiety and repression are presented and discussed in Chapter 5. This begins with discussion of theories of attention in anxiety, where Attentional Control Theory (Eysenck, Derakshan, Santos & Calvo, 2007) emerges as the most compelling model. Following this, theories including repression are introduced, of which the Vigilance-Avoidance Theory (Derakshan, Eysenck & Myers, 2007) provides the strongest model.

Chapter 6 provides a general rationale and outlines the general aims of the present thesis, to be addressed in the empirical studies. Chapter 7 comprises the Stroop-interference study; a classic Stroop colour-word interference task employed to investigate group differences in attentional inhibition of irrelevant information. Chapter 8 reports on a task-switching study, the aim of which was to investigate the influence of bottom-up and top-down factors on attentional control across the experimental groups. The final study, presented in Chapter 9, employed dual-task processing to investigate prospective group differences in characteristic management of attentional processing at different levels of processing load. In addition, this study sought to investigate whether repressors show attentional bias toward discrete stimulus elements. Chapter 10 concludes the dissertation by integrating and discussing the findings from the three empirical studies. The limitations and implications of the findings are also discussed, before the overall conclusion is provided.

Chapter 2: Personality

Defining Personality

Human beings show a natural inclination toward classification. This allows for the development of schemata with which to organise knowledge and form understanding. Given the survival value of social functionality it is likely that people have been attempting to understand the patterns of thoughts, feelings, and actions of others for many thousands of years. According to Burger (2004) consistent patterns in an individual's behaviour and intrapersonal processes constitutes their *personality*. Although accurate, Burger's definition does not sufficiently convey the complexity of psychological concept of personality.

The psychology of personality is very broad and encompasses many theoretical approaches. While this provides a great richness of perspectives, many theorists and researchers fail to integrate their views with others. This has resulted in a field lacking in coherence (Cloninger, 1996; Leary, 2005). Given this, it is difficult to arrive at a comprehensive definition of personality. Indeed, Mischel (1971) points out that there are many definitions of personality, but little consensus. Nevertheless, consistencies emerge from the literature. These predominantly construct personality as a relatively stable and enduring organisation of psychological mechanisms within the individual that influence that person's response to their internal and external environments with consistency sufficient to form a pattern (e.g., DSM-IV-TR; Larsen & Buss, 2008; Leary, 2005). In other words, personality can be thought of as a set of characteristics that influences, with relative consistency, the way an individual thinks, feels, and acts.

Personality Theories

As previously mentioned, the field of personality psychology abounds with theoretical perspectives. While it does not serve the present thesis to elaborate on these perspectives, it is relevant to outline the major metatheoretical approaches to conceptualising personality. The *psychoanalytic* perspective (e.g., Freud, 1923/1962; Jung, 1912/1916) constructs personality as the product of unconscious motivational drives, whereas the *Psychoanalytic-Social* perspective (e.g., Adler, 1936/64; Horney,

1945) includes the cooperation of a consciously aware adaptational self influenced by social and cultural context. The *learning* perspective (e.g., Skinner, 1953; Watson, 1924/1990) holds personality as comprised of habitual behaviours that have been shaped by external reinforcements. Alternatively, the *humanistic* perspective (e.g., Maslow, 1943; Rogers, 1963) posits each individual as being motivated by a fulfilment-directed growth process – *actualisation* – rather than being passively influenced by external forces. The *Cognitive Social Learning* perspective (e.g., Bandura, 1978; Mischel, 1973) on the other hand, emphasises the role observational learning and situational context in influencing internal subjective expectancies about the consequences of behaviour. *Biological* and *evolutionary* perspectives (e.g., Buss, 1991; Eysenck, 1967/2006) are based on the genetic heritability of personality along with the role of biochemistry in behaviour and the adaptive functionality of personality characteristics.

These perspectives differ to varying degrees in their assumptions about the nature of human beings. Burger (2004) suggests that operating from within such distinct approaches to personality is analogous to the six blind men describing an elephant. A less exclusive approach to conceptualising personality is the *trait* perspective (e.g., Allport, 1937; Cattell, 1957). Here, individuals are thought to differ in the characteristics that predominate in their personalities.

Personality Traits

A trait is a theoretical construct describing a dimension of personality that is relatively stable over time and across situations. A major assumption of the trait approach is that traits are psychometrically measurable, typically via self-report questionnaire (Burger, 2004; Cloninger, 1996). Trait approaches also emphasise the multidimensionality and continuous nature of traits. Here, an individual's personality is the product of a complex comprised of their particular position on a number of dimensions (Mischel, 1971). The lack of agreement among theorists concerning the fundamental characteristics of personality has not prevented the broad adoption of the *Big Five* – a five-factor model of personality comprising *Openness to Experience*, *Conscientiousness*, *Extraversion*, *Agreeableness*, and *Neuroticism* (Digman, 1990; Goldberg, 1981; McCrae & Costa, 1992) – as the standard theoretical framework,

despite the inherent limitations concerning comprehensiveness and specificity (Carver & Conner-Smith, 2010; Cloninger, 1996; Funder, 2001). Although the idea that every personality characteristic is applicable to every individual, it is probable that all individuals will fall somewhere along the continuum of some particular fundamental characteristics (Leary, 2005), such as anxiety proneness.

State Anxiety

Anxiety is a state of apprehensive anticipation of prospective danger, misfortune or failure accompanied by dysphoria and/or, somatic symptoms of tension (DSM-IV-TR, p. 820; Colman, 2001, p.46). Maher (1966) would add to this the disruption of effective cognitive control and problem solving. The somatic symptoms of tension referred to are associated with physiological arousal resulting from the activation of the sympathetic nervous system. Psychophysiological measures used to gauge sympathetic activation include heart-rate, respiration rate, palmar sweating (skin conductance), blood-pressure, electromyogram, salivation, pupil size, electroencephalogram and averaged evoked response. Measures such as these are useful as monitors of emotional change, both during the induction and alleviation of anxiety (Lader, 1983).

Barlow (2002) describes anxiety as a preparatory mechanism to attempt to cope with upcoming negative events, suggesting that anxiety is distinguishable from fear, which occurs in the presence of observed threat. Anxiety is a normal reaction to stress. It can activate a stream of processes to mobilise physical and psychological resources to facilitate the negotiation of challenging situations. Spielberger (1966) conceptualised a distinction between anxiety as a psychophysiological state and anxiety as a personality trait. He conceptualised state anxiety as a momentary or situational anxiety that varies in intensity over time and across settings, whereas trait anxiety is conceptualised as a proneness to anxious reactivity. Here, an individual can be considered as relatively higher or lower in trait anxiety depending on their proneness to anxious reactivity (Leary, 2005; Mischel, 1971).

Trait Anxiety

Eysenck (2004) conceptualises trait anxiety as a personality dimension pertaining to individual differences in the tendency to experience anxiety and related negative emotional states. He argues that trait anxiety is more or less akin to Neuroticism (involving traits such as nervousness, tenseness and poor coping with stress), one of the Big Five personality factors proposed by McCrae and Costa (1985). Eysenck's justification for this is two-pronged. First, he makes reference to the positive correlations of around 0.7 typically observed between the two constructs. Second, he refers to the indication from the work of Watson and Clark (1984) that both trait anxiety and neuroticism were relatively pure measures of a broad personality dimension referred to as negative affectivity. Eysenck, however, does not go so far as to suggest that these constructs are one and the same. Here, he refers to their relationship to the personality dimension of *extraversion* – where neuroticism is typically shown to be orthogonal, while trait anxiety tends to show weak negative correlation (Eysenck & Eysenck, 1985).

It is important to demonstrate the strength of similarity between trait anxiety and neuroticism because the overwhelming proportion of personality research is dedicated to the very well established Big Five personality factors. This close relationship makes the wealth of research into neuroticism theoretically useful to the study of trait anxiety.

The strong association with trait anxiety means the fund of research into neuroticism can provide important direction when considering aspects of trait anxiety, such as potential biological factors involved. For instance, in a comprehensive study involving large numbers of monozygotic and dizygotic twin pairs raised either together or apart, Pedersen, Plomin, McClearn, & Lars (1988) found that genetic factors accounted for approximately 31% of individual differences in neuroticism (from Eysenck, 2004). This proportion of genetic contribution is similar to those reported in other studies of twins and neuroticism (see Eysenck, 1992, for a review).

A second biological factor thought to be involved in trait anxiety is physiological reactivity or responsiveness. Here, it would be expected that individuals high in trait anxiety or neuroticism would show greater physiological responsiveness than those low in trait anxiety on indices of physiological arousal, particularly under stressful conditions (e.g., Eysenck, 1967; Gray, 1982). While compelling, this theory continually

failed to gain reliable support, with decades of consistent non-significant findings in non-stressful, moderate stressful and highly stressful conditions (Eysenck, 2004).

A crucial step toward the demystification of the apparently antithetical lack of support for the proposition of differential physiological responsiveness came from the work of Weinberger, Schwartz, and Davidson (1979) showing that trait anxiety was more complex than conventional evaluation allowed. By combining a measure of trait anxiety with a measure of psychological defensiveness they demonstrated that people scoring low on trait anxiety did not comprise a heterogeneous group. Instead, two distinct groups emerged: a *truly* low anxious group, that reported low trait anxiety, and showed low defensiveness; and a *repressor* group, that reported low trait anxiety, but showed high defensiveness. Weinberger et al. found a clear effect, whereby repressors' claims of low anxiety were contradicted by their behavioural and physiological responses to stress.

While the concept of a repressive coping style in the context of anxiety will be discussed more in the next section, it does raise the question of the role of cognitions in trait anxiety. A wholly biological explanation for trait-anxiety requires not only situational consistency, but also constancy over time. In a longitudinal study of various factors, Conley (1984) found only moderate consistency for neuroticism over a long period of time. Further, despite ongoing debate in psychological research over the relative contributions individual and situational factors in human behaviour, few, if any, would still argue that context has no effect on psychological experience. Put more simply, no rational argument remains against the *interactionist* perspective – the concept in personality research of a bidirectional affective relationship between psychological disposition and situational factors.

There are several views on the composition of cognitive dimensions thought to comprise trait-anxiety (e.g., Endler, 1983; Williams, Watts, MacLeod, & Matthews, 1988 & 1997; Eysenck, 1992). The most compelling of these is presented by Eysenck and colleagues (Eysenck, 2004; Eysenck, Derakshan, Santos, & Calvo, 2007). The central tenet of Eysenck's cognitive perspective is that various cognitive biases are responsible for an individual's level of trait anxiety. He argues that the two most important of these are attentional bias (the tendency to selectively attend to threat-related

stimuli) and interpretive bias (the tendency to interpret ambiguous stimuli or events as threatening), and that together these biases effect a more threatening impression of an environment.

Although the evidence relating to trait-anxiety and attentional biases is extensive (for reviews see Eysenck, 1992; Mathews & MacLeod, 1994; Williams, Matthews, & MacLeod, 1996) much of this is correlational and gives no indication of the directionality of effects in the relationship between trait-anxiety and cognitive biases. Nevertheless, evidence relating to causality has been found. Mathews and Mackintosh (2000) found increased state-anxiety in individuals following manipulations designed to increase interpretive bias. Further, MacLeod, Rutherford, Campbell, Ebsworthy, and Holker (2002) found reduced anxiety in individuals who participated in a long training programme designed to reduce attentional bias.

Humans have been shown to vary not only in proneness to anxiety as a personality trait, but also in their management of it. Anxiety symptoms are typically uncomfortable and impair higher-order cognitive function. A common method used to mitigate this experience is behavioural avoidance of anxiety-provoking situations. Other methods include the employment of psychological strategies to mitigate the effects of anxiety symptoms. One strategy in particular functions to shield the individual from consciously experiencing anxiety. This is the strategy of *repression*.

Repressive Coping Style

Freud (1915/1957) is typically credited with first use of the term ‘repression’ to describe the concept of a psychological defence strategy for the avoidance of negative emotional states associated with anxiety. He proposed the operation of cognitive processes that function to deflect personally threatening material from conscious awareness (Derakshan, Eysenck, & Myers, 2007; Freud, 1915/1957; Furnham, Petrides, Sisterson, & Baluch, 2003). Despite much contention regarding the validity of this concept in the context of a ‘sophisticated unconscious’ (see Rofé, 2008, for a review) the construct of repression remains relevant in contemporary research.

Early scientific studies into repressive coping were characterised by inconclusive results (Furnham et al., 2003). This was due in part to the lack of discriminant validity

afforded by classification methods in use at the time (Derakshan et al., 2007; Furnham et al., 2003). A watershed in the study of repressive coping style was produced by Weinberger et al. (1979). Their work provided two pivotal contributions to the area. First, they established what remains as the most influential process for identifying repressors (Derakshan et al., 2007). Weinberger et al. classified repressors according to the combination of low self-reported trait-anxiety on the Manifest Anxiety Scale (Taylor, 1953) and high psychological defensiveness as indexed by scores on the Marlowe-Crowne Social Desirability Scale (MCSDS; Crowne & Marlowe, 1960). Although repressors have been identified using a number of instruments, or combinations of instruments (for examples, see Derakshan et al., 2007; Furnham et al., 2003), and more contemporary research has typically substituted the Trait Version of the State-Trait Anxiety Scale (STAI-T; Spielberger et al., 1983) for the Manifest Anxiety Scale (e.g., Bar-Haim, Lamy, & Glickman, 2005; Bromfield & Turpin, 2005; Derakshan & Eysenck, 2001; Fox, 1994), the essential combination of low trait-anxiety and high psychological defensiveness used by Weinberger et al. remains by far the most influential (Derakshan et al., 2007).

The second major contribution of Weinberger et al. (1979) was their finding that repressors, contrary to self-report, demonstrated higher levels of anxiety than truly low trait-anxious participants on both behavioural and psychophysiological indices. Indeed, repressors showed a tendency far more consistent with high trait-anxious participants on these measures. Similar discrepancies have been found numerous times since (for a review, see Schwerdtfeger & Kohlmann, 2004), and have become definitive of the repressive coping style (Derakshan et al., 2007).

A solid body of evidence exists for the construct validity of a repressive coping style in the context of anxiety (see Derakshan et al., 2007, for a review). While much of this evidence is discussed in Chapter 4, it is relevant here to outline the major understandings that have emanated from this. Repressors appear to avoid experiencing anxiety through strategic appraisal and management of external and internal events. They show an enhanced preattentive sensitivity to potential-threat, whereby material identified as threatening is diverted from conscious awareness through active de-selection. Here,

ambiguous material is thought to remain available for selection, where repressors show a tendency for non-threatening interpretation (Derakshan et al., 2007).

The unconscious engagement of cognitive mechanisms toward more effective function is well established in cognitive psychology. In the context of human evolution, an overactive threat-detection system makes sense, as does the development of strategies to manage efficient processing. Hence, a tendency to disregard or minimise unpleasant events may be advantageous in two ways. First, it may assist in the maintenance of attention on current goals by blocking prospective task-irrelevant negative distractors. Second, it would likely facilitate mood regulation through the reduction of negative input to consciousness (Eysenck et al., 2007; Mogg et al., 2000).

Nevertheless, the anomaly of a repressive coping style to the otherwise neatly continuous construct of trait anxiety creates a taxonomic awkwardness. It forces the distinction and combination of two dimensions; one relating to threat sensitivity, the other to unconscious strategic management. This awkwardness will not be resolved through repealing the categorical distinction of a repressive coping style. Instead, it is more practical to work within the tension. Such practicalities are also necessary when working with complex concepts, such as attention.

Chapter 3: Attention

Defining Attention

Attention has been referred to as one of the vaguest constructs in psychology (Eysenck, 1988). Although the singular nature of the term is suggestive of a unitary concept, this is not the case. The construct of attention comprises a complex of multiple dissociable processes, the interdependence of which can, at times, give the impression of amorphousness (Derryberry & Reed, 2002; Eysenck, 1988; Luck & Vecera, 2002; Pashler, 1994). Of these processes, those relevant to the current thesis will be introduced through this chapter and discussed in more detail in the experimental chapters.

James' (1890) definition of attention as the preferential selection for processing of some information above others asserts the major premiss that has underpinned all major theories of attention – that human information processing capacity is limited (e.g., Kahneman, 1973; Lavie, de Fockert, & Viding, 2004; Tombu & Jolicœur, 2005; Wickens, 1984). Overwhelmingly accepted, the concept of a limited capacity necessitates preferential processing for efficiency and overload prevention. The concept of the strategic elevation of some particulars for higher order processing has come to be referred to as *selective attention*.

Selective Attention

Selective attention is crucial to the execution of goal-directed behaviour. It requires focussing processing resources on goal-relevant information while actively suppressing processing of goal-irrelevant information (Lavie et al., 2004; Leung, Skudlarski, Gatenby, Peterson, & Gore, 2000). For the purposes of this thesis, selective attention is defined as the selection for preferential processing of information according to its meaningfulness relative to the goals, whether conscious or not, of the individual, whilst modulating processing of that which is less so. This notion of streamlining the processing of relevant information from a competitive field has been central to attempts to understand how particular information is selected above others for more elaborate processing.

Selective Attention Theory

Relatively articulate models of selective attention began to emerge in the 1950s. Known as the Bottleneck Theories, these models emanated from experimentation using the Dichotic Listening paradigm and focussed on the channelling/filtering/selection of information. Broadbent's (1958) *Filter Model* is typically credited as the first of the Bottleneck Theories. He proposed that all incoming stimuli undergo preattentive analysis in a sensory buffer. From here, a filter allows narrow passage to select stimuli based on physical characteristic for more elaborate processing/conscious attention (e.g., semantic analysis). He suggested that stimuli rejected by the filter rapidly decay, never to reach consciousness.

Among other deficiencies, Broadbent's (1958) all-or-nothing Filter Model could not account for what Cherry (1953) termed 'the cocktail party problem'. Treisman (1960) addressed such intrusions into consciousness with her *Attenuation Theory*. While largely retaining Broadbent's Filter Model (bottleneck occurs prior to pattern recognition stage), she proposed that unattended signals were attenuated, rather than blocked completely. She suggested that particularly salient signals (e.g., emotional ones) were endowed with a lower triggering threshold, which accounted for passage to semantic analysis and then into consciousness.

Deutsch and Deutsch (1963) agreed with Treisman's (1960) proposition of discrimination mechanisms that operated on both physical and semantic properties, but disagreed on the serial aspects of these. Deutsch and Deutsch suggested that all signals were processed in parallel, with competition for selection being resolved through activation dominance according to salience loadings. This represents the first of what have become known as *late-selection theories*, distinguishable from *early-selection theories* – such as Broadbent's (1958) and Treisman's – by the occurrence of the bottleneck following semantic analysis of unattended information. An early- versus late-selection debate quickly ensued and has remained unresolved since.

The abundance of evidence favouring either early- or late-selection hints that selective attentional processing may be more flexible than previously thought. This is the view taken in the *Load Theory* proposed by Lavie et al. (2004), who put forward a hybrid model where either early- or late-selection can occur depending on the nature of

demands. Through a series of experiments varying perceptual and working memory loads to investigate the effects of irrelevant distractor interference on a visual selective attention task, Lavie et al. presented evidence supporting two dissociable mechanisms of selective attention: a relatively passive early perceptual mechanism that operates in situations of high perceptual load to exclude irrelevant stimuli, and a more active cognitive control mechanism that operates in situations of low perceptual load to reject irrelevant stimuli when these are perceived. Though never explicitly stated by Lavie et al., these mechanisms are basically akin to *bottom-up* (stimulus-driven) and *top-down* (context-driven) information processing, respectively.

With the probable exception of the most rudimentary mechanisms involved in attention capture, allocation of attention is influenced by both bottom-up and top-down processes (Desimone & Duncan, 1995; Luck & Vecera, 2002). Different attentional systems operate in different ways depending on situational demands (Luck & Vecera, 2002). The characteristics of these demands can vary from spatial locations and stimulus features, to complex abstractive components (Luck & Vecera, 2002).

Regardless of whether the attentional processing requirements of a situation are more reflexive, or more voluntary (i.e., intentional, goal-driven), a comprehensive model of the complex cooperative involved in selective attention is yet to be articulated (Lavie et al., 2004). Yiend and colleagues (2010) support the observation of a preference in the current attention literature for the *biased competition* (Desimone & Duncan, 1995) approach, where top-down expectancies enhance stimulus-driven neural activity in order to affect the kind of competition for selection proposed by Deutsch and Deutsch (1963).

Component Processes of Selective Attention

Despite the lack of certainty concerning the complexities of selective attentional processing, it remains possible to understand some of the fundamental component processes involved. Over a number of decades Posner and colleagues (Posner & Petersen, 1990; Posner & Raichle, 1994; Posner & Rothbart, 1998) have produced evidence supporting a robust model of visual attention that comprises dissociable systems involving involuntary and voluntary processes. Based in the parietal regions of the brain, the posterior system is concerned with the more reactive, mechanistic

operation of orienting attentional resources. This is achieved through the component processes of attentional disengagement, shift and engagement.

The posterior attentional system communicates with the anterior attentional system. Based in the frontal regions – primarily the anterior cingulate cortex – the anterior system handles the more volitional aspects of attention. Through connections with the limbic and frontal motivational systems the anterior system performs executive level processes, such as inhibition of dominant conceptualisation and response patterns, and error detection. Hence, the anterior system can function as a regulator of the posterior orienting system, allowing voluntary control over allocation of attention according to motives and expectancies (Derryberry and Reed, 2002).

This modelling of attention by Posner and his colleagues (Posner & Petersen, 1990; Posner & Raichle, 1994; Posner & Rothbart, 1998) has been formed in the context of the visual orienting. Yiend (2010), however, discusses how the compelling nature of the modelled processes has seen researchers extend them to a non-modality-specific concept of attentional orienting. She suggests that orienting – as a process of moving attention to a space, time, stimulus dimension, etc. – can be seen as an example of how selection may occur, given the implication of phenomenal amplification.

The extension of the mechanisms of disengagement, shifting and engagement to the context of a generalised orienting of attention requires some clarification. *Disengagement* refers to the suppression of activity associated with attending by withdrawal or inhibition (Posner & Petersen, 1990; Yiend, 2010). It can be thought of as the process of active de-selection. *Shifting* refers to the movement of focal attention from one selected point to another (Posner & Petersen, 1990; Yiend, 2010), both within and across modalities. *Engagement* is the concentration of attentional resources on some particular, which may be in the form of a stimulus or location (Posner & Petersen, 1990), or some other phenomena, such as a thought. For Yiend, engagement and selection are one and the same. As these processes interrelate to affect each other, functional performance is subject to cooperative dynamic attunement.

The relationships between the mechanisms of disengagement, shifting, and engagement require sufficient balance to allow the flexibility needed for adequate operation. For example, attentional grip needs to be moderated to simultaneously avoid

both unhelpful dwelling and distraction. This balance extends to the retention of adequate resources for the performance of the more peripheral prossessing involved in general attentional orienting, such as monitoring and buffering across exogenous and endogenous domains. It follows that attentional resource allocation must be managed in a way that allows the dynamic cooperation across such a complex of operations. Thus, attentional mechanisms operate under some form of control.

Attentional Control

As discussed earlier, managing the coordinated application of cognitive resources to performance achievement necessitates strategic control of attentional processes. While empirical evidence around the neurological substrates involved is improving, this remains largely desultory in nature and the mechanisms of selective attentional control remain unclear (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van Ijzendoorm, 2007; Hopfinger, Buonocore, & Mangun, 2000; Lavie et al., 2004; Yiend, 2010). It is clear that attention can be controlled by goals in a top-down manner (Posner & Rothbart, 2007). This involves a complexity that makes elucidation of the functional divisions involved very difficult. Hence, defining the concept of attentional control is inherently problematic (Yiend, 2010).

For Bargh (1994) attentional control relates to the ability to alter or cease a process once it has begun. Moors and DeHouwer (2006) extend this to include the initiation of processes. Yiend (2010) agrees with Moors and DeHouwer, though she uses the term intentionality. Raz and Buhle (2006), in addition to the ability to activate, sustain, or inhibit a response, stipulate the capacity for inhibition of a dominant response in favour of a subdominant response. Similarly, Posner and Rothbart (2007) refer to conflict monitoring and resolution in their discussion of what they term *executive attention*, which specifically encompasses thoughts and feelings, as well as behavioural responses. Derryberry and Reed (2002) also base their concept of attentional control on the idea of executive control processes. They use the anterior and posterior attentional systems model – described in the previous section (see Posner & Petersen, 1990) – to emphasise the role of the volitional control of attentional orienting.

The vagueness of some of the definitions presented is understandable in the context of the expanse between purely reflexive sensory processes and those of meta-cognition. Nevertheless, there appears to be an emphasis on the notion of conscious intentionality that may provide the strongest point of divergence. Regardless, the resolution of what constitutes attentional control is not central to the present thesis. Instead, it is sufficient to hold some understanding of the concept for the consideration of some of the theories on the relationship between selective attention, anxiety and repression. The most pertinent of these will be presented, along with relevant empirical evidence, in Chapter 5. Prior to that, however, it is prudent to interpose with discussion of human event-related brain potentials, a common psychophysiological measure which has provided researchers a means with which to investigate the subtle sub-processes involved in attentional processing.

Chapter 4: Event-Related Potentials (ERPs)

Event-Related Potentials (ERPs)

Event-related brain potentials (ERPs) are objective indices of brain activity related to cognitive processing. ERPs emanate from postsynaptic electrical signals generated during the process of neurotransmission. Those passing through the skull are recorded from the scalp as voltage changes that comprise the electroencephalogram (EEG). Event-locked epochs of the EEG are averaged to produce ERPs. Sufficient numbers of epochs allow for unrelated brain activity to be averaged out to zero, leaving a profile of the averaged activity related to the processing of a definable event (Luck, Woodman, & Vogel, 2000).

The ERP profile appears as a waveform of positive and negative voltage deflections, typically called peaks, or components. These are defined in terms of their polarity, latency, scalp distribution, and tendency to covary with experimental manipulations (Fabiani, Gratton, & Coles, 2000; Friedman, Cycowicz, & Gaeta, 2001; Picton et al., 2000). The peak amplitude of a component is considered to reflect the processing intensity, while peak latencies are considered to index processing time (Kok, 2001). Components are typically named according to polarity and timing of their peak. For instance, P1 would indicate the first positive-going peak, whereas P150 would indicate a more precise latency around 150ms. The sequence of components reflects the sequence of neural operations associated with processing an event – from early sensory processes, through to decisional and response-related processes (Empson, 1986; Luck et al., 2000; Picton et al., 2000).

Although the high temporal resolution of ERPs, which is in the order of milliseconds, allows for excellent information on the timing of neural processes, ERPs afford relatively poor spatial resolution, and so are not well suited to identifying the neural structures involved (Empson, 1986; Fabiani et al., 2000; Friedman et al., 2001; Hopfinger et al., 2000; Luck & Vecera, 2002, p. 263; Luck et al., 2000; Picton et al., 2000). Nevertheless, ERPs have the capacity to provide a continuous measure of the processing, allowing insight into the timing and intensity of neural processes running in close temporal sequence. This makes ERPs particularly well suited to the study of

attentional processes (Harter, Miller, Price, LaLonde, & Keyes, 1989; Hillyard & Anllo-Vento, 1998; Kathmann, von Recum, Haag & Engel, 2000; Luck & Vecera, 2002; Luck et al., 2000; Mangun & Hillyard, 1995).

ERP components are sensitive to both the physical properties of a stimulus, and the psychological processes invoked by it. Components occurring within the first 80ms following stimulus onset are regarded as obligatory sensory responses to the physical properties of the eliciting stimulus (e.g., sensory modality, intensity, and quality of information), and are typically referred to as exogenous components (Empson, 1986; Fabiani et al., 2000; Picton et al., 2000). In contrast, components emanating from the processing of aspects of an event that are extrinsic to the physical properties of the eliciting stimulus are referred to as endogenous (Empson, 1986; Picton et al., 2000). Interpolating the purely exogenous and purely endogenous ERP components are those sensitive to both the physical and the psychological properties of stimuli, the mesogenous components.

The mesogenous components typically occur between approximately 100 and 300ms post-stimulus onset. The N1, P2, and N2 components may all be considered mesogenous (Fabiani et al., 2000). As the next component in the processing stream, the P3 is considered to be the first of the endogenous components (Fabiani et al., 2000). The N1 and P3 components are most commonly associated with the timing and intensity of cognitive processing involved in selective attention, due to their establishment as indices of early selection, and focussed attentional processing, respectively (Fabiani et al., 2000; Hillyard & Anllo-Vento, 1998; Kok, 1997, 2001; Parasuraman, 1980; Polich, 2007). Nevertheless, the middle-latency components, P2 (Crowley & Colrain, 2004; Freunberger, Klimesch, Doppelmayr, & Höller, 2007) and N2 have also been implicated (Fabiani et al., 2000; Hillyard & Anllo-Vento, 1998; Parasuraman, 1980). Hence, these four ERP components are those of primary interest to the current thesis.

It is important to acknowledge that the use of broad descriptors, such as P3, is simplistic and belies the complexity of composite subcomponentry. Indeed, it is well established that each deflection of the ERP is comprised of several temporally overlapping subcomponents, each generated by parallel streams of neural activity (Crowley & Colrain, 2004). Hence, the use of such broad descriptors is undertaken

advisedly at present, with greater definition of the ERP componentry concerned to be developed in course. The next section of the current chapter is concerned with introducing these components as indices of attentional processing.

ERPs and Attention

Over the past four decades ERPs have played an increasingly important role in understanding the mechanisms of attention (Luck et al., 2000). Over this time researchers have analysed ERP behaviour in response to manipulation of attention-related variables in a wide range of paradigms. The resultant growth of literature relating to the attentional correlates of ERPs has seen the functional interpretation of ERP componentry become an increasingly complex matter. An exhaustive review of this literature is impracticable. Instead, it is more practical to discuss that which is relevant to the present thesis. The synthesis presented in this chapter focuses primarily on processing in the visual modality, with the auditory modality addressed more fully in Chapter 9.

N1

The N1 component is a negative deflection that typically peaks between 100 and 200ms post-stimulus-onset. It is observed in response to both auditory and visual stimuli, and is associated with early attentional processing (Haider, Spong & Lindsley, 1964; Kieffaber & Hetrick, 2005; Kok, 1997, 2001; Mangun & Hillyard, 1990). In the visual modality, N1 is commonly detected at occipital, parietal, central, and frontal sites (Mangun & Hillyard, 1991). This broad distribution, and tendency to peak earlier over frontal than posterior sites (Ciesielski & French, 1989; Mangun & Hillyard, 1990; Vogel and Luck, 2000), is suggestive of multiple neural and cognitive correlates (Clark, Fan, & Hillyard, 1995; Crowley & Colrain, 2004; Makeig et al., 1999; Vogel and Luck, 2000). Despite the lack of clarity concerning the neural systems involved, it is clear that the variety of processes indexed by N1 are inclusive of an order higher than basic registration of stimulus features (Kok, 1997; Wascher, Hoffmann, Sänger, & Grosjean, 2009).

The positive relationship between N1 amplitude and attention is customarily interpreted as reflecting the allocation of perceptual resources. More specifically, the selective attention-related modulation of N1 has often seen this interpretation extended to the operation of sensory gain and filtering type mechanisms (Kok, 1997; Hillyard & Kutas, 1983; Luck et al., 2000; Rugg, Milner, Lines, & Phalp, 1987). Further, in addition to indexing the attentional amplification of sensory inputs, N1 has been shown to be linked with visual discrimination processes (e.g., Mangun & Hillyard, 1991).

Vogel and Luck (2000) demonstrated the sensitivity of N1 to differentiating between classes of stimuli. They found an N1 discrimination effect for both colour- and form-based discriminations, regardless of whether a response was required. Further, Vogel and Luck reported the magnitude of this effect to be equal for easy and difficult discriminations. They interpreted these results as being consistent with the hypothesis that visual N1 reflects a discrimination process operating within focal attention.

Wascher et al. (2009) agree that N1 processing exceeds basic encoding. They reason that while the processing reflected in N1 is initially driven by incoming information it is strongly influenced by higher order processes. Wascher et al. propose that N1 reflects the initial functional integration of multiple sources of information that is presumed to occur in early selection processes. Whether or not this is indeed the case, there is sufficient evidence to suggest that N1 amplitude provides an index of the attentional processes involved in early selection for further processing.

P2

The P2 component typically peaks between 150-300 milliseconds post-stimulus onset. It shows a similar topography for auditory and visual modalities, where distributions centring around fronto-central and occipito-parietal regions tend to produce a maxima at the vertex (Crowley & Colrain, 2004; Oades, Zerbin, & Dittmann-Balcar, 1995; O'Donnell, Swearer, Smith, Hokama, & McCarley, 1997; Roth, Ford, Lewis, & Kopell, 1976). Although P2 typically co-varies with N1 on many stimulus dimensions, it has been successfully dissociated experimentally, developmentally, and topographically (Crowley & Colrain, 2004). Despite evidence distinguishing P2 from N1 (e.g., Knight, Hillyard, Woods, & Neville, 1980; Knight, Scabini, Woods, & Clayworth, 1988;

Ogilvie, Simons, Kuderian, MacDonald, & Rustenburg, 1991), until relatively recently P2 was typically regarded as an intrinsic element of the N1-P2 complex, or 'vertex potential' (Crowley & Colrain, 2004). This has contributed to the paucity of studies focused on P2 as a unitary component. Hence, remarkably little is known about the underlying neurological correlates or functional significance of P2 (Crowley & Colrain, 2004; Freunberger et al., 2007).

Despite the dearth of studies focussed on elucidating the significance of P2, some researchers have speculated indirectly on the functional role of positive deflections occurring around 200ms. For instance, Novak, Ritter and Vaughan (1992) described a 'non-target positivity' at fronto-central sites in response to non-target stimuli in an auditory oddball task. They interpreted this as reflecting an attention-modulated process associated with the performance of an auditory discrimination task.

Similarly, Garcia-Larrea, Lukaszewicz and Mauguiére (1992) reported an enhanced positivity around frontal regions at around 250ms in response to non-target stimuli in an auditory oddball task. Garcia-Larrea et al. speculated that this component reflected cognitive processing associated with target identification, representing a necessary step for elicitation of the P3 associated with cognitive evaluation. Crowley and Colrain (2004) suggest that the frontal prominence of these effects can be associated with regions involved in preventing interference by irrelevant stimuli, and have proposed that P2 can be interpreted as indexing some aspect of stimulus classification.

Similar interpretations have been posited in the visual modality, where P2 has been linked to spatial filtering and the process of feature discrimination and stimulus categorization (O'Donnell et al., 1997). Freunberger et al. (2007) investigated whether visual perception processing was sensitive to top-down information about stimulus classification. They used a visual priming task where participants classified photographic subjects as either living or non-living, and found larger P2 amplitude at parieto-occipital sites for incongruent, compared to congruent targets.

Freunberger et al. (2007) interpreted the increased P2 amplitude for incongruent targets as reflecting the enhanced cognitive processing demands associated with reconciling the interference caused by violation of top-down expectancy, generated through priming. Taken together, the evidence presented above suggests that P2 is

sensitive to operations involved in selective attention. It appears to have capacity to provide some index of the cognitive resources allocated to processes associated with the facilitation of feature detection and stimulus discrimination, including interference reconciliation, at early stages of encoding.

N2

The N2 component generally peaks between 200ms and 350ms post stimulus onset. Typically maximal at fronto-central sites in both the auditory and visual modalities, a posterior subcomponent is also observed around temporal and occipital regions in the visual modality (Folstein & Van Petten, 2008). This posterior N2 is sensitive to probability and is considered to provide an index of the degree of attentional resources allocated to the processing of stimuli in the visual cortex (Luck & Hillyard, 1994; Suwazono, Machado, & Knight, 2000). There has been broad agreement on the existence of multiple subcomponents comprising N2 for some time (see Pritchard, Shappell, & Brandt, 1991). Despite this, however, relative to mismatch negativity, consensus around the specifics of these is yet to be demonstrated in the current literature (for a review, see Folstein & Van Petten, 2008).

For instance, the common association of anterior 'no-go' N2 with response inhibition (e.g., Kok, 1986; Kopp, Rist, & Mattler, 1996) has recently been challenged by findings presented by Niewenhuis, Yeung, van den Wildenberg and Ridderinkhof (2003), and Donkers and van Boxtel (2004). These groups each conducted an independent experiment using operationally distinct go/no-go tasks. Both groups reported results that unequivocally supported interpretation of anterior N2 as modulated primarily by activity associated with conflict monitoring processes, with very little, if any, effect by operations associated with the inhibition of prepotent responses.

Similarly, Yeung, Botvinick, and Cohen (2004) argued for a conflict monitoring explanation for the anterior N2 they observed in a flanker task (B.A. Eriksen & Eriksen, 1974) experiment conducted to investigate the relationship between conflict-monitoring in error-related negativity (ERN). They suggest that the conflict monitoring theory is consistent with the proposition of Ritter, Simson, Vaughan, and Friedman (1979) and Ritter, Simson, Vaughan, and Macht (1982) that anterior N2 is related to decision or

categorisation processes. On the question of what neural structures may be involved in conflict monitoring, Yeung et al. show agreement with Niewenhuis et al. (2003) and Donkers and van Boxtel (2004) that, as with other cognitive control operations, the major processing is likely to take place in the anterior cingulate cortices (ACC).

In recent review, Folstein and Van Petten (2008) propose the division of frontally distributed N2 into subcomponentry that may reflect sub-functions of the ACC. They stipulate two classes of subcomponents: novelty, or deviance-related; and control-related. Folstein and Van Petten nominate a number of candidate subcomponents under the mantle of control-related: No-Go N2, conflict N2, rare target N2, stop-signal N2, and even ERN and Stroop N450. In light of these multiple functional correlates, Folstein and Van Petten stipulate that fronto-central N2 cannot be interpreted in isolation.

Although there remains some of lack clarity on the specific functional correlates of the anterior N2, the convergence apparent in the more recent literature has provided increased elucidation. The observation of anterior N2 in response to tasks that require strategic monitoring (e.g., Go/No-Go, Stop Signal, and Flanker Task), independent of mismatch detection, demonstrates the influence of cognitive control processes on this component. The past decade has seen a shift away from the interpretation of anterior N2 as indexing the inhibition of prepotent response in favour of a primary association with conflict monitoring processes related to decisional or categorisation operations.

P3

The P3 component is likely the most studied aspect of the human ERP (Kok, 2001). Elicited in all five sensory modalities, it is customarily divided into two subcomponents according to scalp distribution and functional correlates (Folstein & van Petten, 2008). The frontally maximal P3a typically peaks between 250ms and 280ms. It is associated with the engagement of attentional resources to unexpected or novel events (Comerchero & Polich, 1999; Polich, 2003). The P3b, on the other hand, is more ubiquitous. It has a more parietal maximum and tends to peak later than the P3a, typically between 250ms and 500ms post stimulus onset (Polich, 2007). The P3b is commonly considered the classic P3 component. Given this, and that the present thesis does not focus on P3a, unless otherwise stated, P3b will be referred to simply as P3 from here on.

The classic P3 is considered the first wholly endogenous ERP component (Donchin, 1981; Johnson, 1986). While the concert of evidence from neuroimaging and lesion studies implicates the temporo-parietal lobe junctions in the generation of P3 (Polich, 2007; Polich & Criado, 2006; Verleger, Jaśkowski, & Wascher, 2005), there is also evidence of contribution from frontal regions, such as the anterior cingulate cortex (Kok, 2001; Polich, 2007). Despite improved understanding around the associated functional correlates, over decades of research across a wide variety of experimental paradigms, a resounding model has yet to be achieved (Kok, 1997; Verleger et al., 2005). While this can make discussion of the P3 cumbersome, there is sufficient agreement in the literature to allow reasoned functional interpretation.

In broad terms, P3 is generally thought to reflect processing involved in the evaluation or categorisation of task-relevant stimulus events (Donchin, 1981; Hillyard & Kutas, 1983). The observation of a negative correlation between amplitude and event probability led Donchin to propose a context-updating hypothesis where P3 reflects the activation of resources associated with a previously inert contextual schema. This is not necessarily inconsistent with the suggestion of Hillyard and Kutas, that P3 involves the operation of a later stage of selection, where early sensory information (processed at the N1 stage) is compared with memorised templates or internal models. These hypotheses do not, however, account for the modulation of P3 amplitude by factors independent of probability.

In an early articulation of these factors, Johnson (1986) outlined the effects of both *information transmission* and *stimulus meaning* on P3 amplitude. Regarding information transmission, he argued that loss of available stimulus information through equivocation or inattention results in lower amplitudes. Stimulus meaning was used by Johnson as an umbrella term for three independent variables: task complexity, stimulus complexity, and stimulus value (or significance). His attribution for the positive relationship between each of these and P3 amplitude, as due to increased processing requirements, is consistent with earlier conceptualisations of P3 amplitude as an index of cognitive workload and attentional resource allocation (e.g., Donchin, 1981; Isreal, Wickens, & Donchin, 1979; Isreal, Chesney, Wickens, & Donchin, 1980a, 1980b; Donchin & Isreal, 1980; Wickens, Isreal, & Donchin, 1977).

Kok (2001) also agrees with the notion of P3 as an index of cognitive workload. He reviewed the relevant literature in his synthesis, *On the utility of P3 amplitude as a measure of processing capacity*. This included the dual-task paradigm, where two qualitatively distinct tasks are performed simultaneously (e.g., Donchin, 1981; Isreal et al., 1979; Isreal et al., 1980a, 1980b; Donchin & Isreal, 1980; Wickens et al., 1977). Here, increasing the difficulty or priority of one task results in fewer resources being available to process the other; as evidenced by reduced P3 amplitude and, or, performance (Donchin, 1981; Kok, 2001).

In addition to the conceptualisation of P3 amplitude as an index of attentional resource allocation, Kok (2001) agrees with Donchin (1981) that P3 reflects some event categorisation process. He discusses a template-matching model that is similar to Donchin's context-updating hypothesis; particularly with regard to the requisite operation of working memory in the process of target recognition. For Kok, P3 amplitude reflects the processing involved in an event categorisation network that is controlled by the cooperation of attention and working memory. Despite the strong support for the event categorisation model, other theories have been proposed.

Verleger et al. (2005) provide a strong alternative to the event categorisation account of P3; one which challenges the commonly held assumption that P3 is independent of response processing. Verleger et al. propose that P3 reflects operations concerned with monitoring whether the initial classification of a stimulus has been appropriately translated into action. This proposition is based on their findings of no difference between stimulus- and response-locked P3 amplitude, and peak- and response-latency covariance. Additionally, Verleger et al. cite the fact that P3 amplitude is reduced, rather than increased, with difficulty of stimulus classification (e.g., Johnson, 1988; Ruchkin & Sutton, 1978; Verleger, Gasser, & Möcks, 1985). Hence, for Verleger et al. P3 reflects the consequence of a decision, rather than the process of deciding.

Despite the lack of consensus regarding the functional significance of P3, there is wide agreement on some general principals. It reflects the activation of cognitive resources concerned with processing involved in the final stages of higher-order selective attention. It requires directed attention, at the level of consciousness, to the processing of information that has been internally conditioned as salient. Further, this

processing is concerned with guiding action previously determined as appropriate. The sensitivity of P3 to manipulations of factors that affect attentional resource requirements (e.g., Donchin, 1981; Johnson, 1986) has been well established. Hence, the P3 component is commonly considered to provide a useful index of the attentional resource activation involved in decision making processes (Donchin, 1981; Isreal et al., 1980a, 1980b; Johnson, 1986; Kok, 1997, 2001; Polich, 2007; Verleger et al., 2005).

Chapter 5: Anxiety, Repression and Attention

The previous chapters addressed the concept of selective attention, including the influence of bottom-up and top-down input on the coordination of the component processes of disengagement, shifting and engagement (Posner & Petersen, 1990; Yiend, 2010). ERP methodology was also introduced, along with discussion around the functional significance of the N1, P2, N2 and P3 components of the ERP. The present chapter is concerned with presenting theory and evidence pertaining to selective attentional processing in the context of trait-anxiety and repression. The dearth of pertinent research evidence will become evident from the desultory array of relevant findings integrated with the theories throughout the remainder of this chapter.

Theories of Attention and Anxiety

There is a compelling body of evidence demonstrating a threat-related attentional bias associated with anxiety (e.g., Eysenck & Byrne, 1992; Fox, Russo, & Dutton, 2002; Mogg & Bradley, 1998; Wilson & MacLeod, 2003). Despite the clear presence of a bias for threat in anxiety, and the rapid growth of empirical research into the relationship between attention and anxiety, the area is still in its infancy theoretically (Yiend, 2010). Nevertheless, a number of theories around the mechanisms underlying the threat-related bias in anxiety have been proposed. While not exhaustive, those presented below offer a sufficient overview of the most popular of these.

Williams et al. (1988, 1997) have proposed that the threat-related bias observed in anxious individuals is underpinned by two cognitive mechanisms: an Affective Decision Mechanism (ADM) and a Resource Allocation Mechanism (RAM). The ADM evaluates the threat value of stimuli. The RAM allocates attentional resources according to input received from the ADM. Williams et al. propose that individual differences in trait-anxiety affect RAM activity, whereby individuals high in trait-anxiety are predisposed to orienting toward threat, while those low in trait-anxiety tend to shift attention away from threat.

The *cognitive-motivational model* proposed by Mogg and Bradley (1998) also specifies two cognitive mechanisms: a valence evaluation system (VES) that is similar

to the ADM of Williams et al. (1988, 1997), and a goal engagement system (GES) that is similar to the RAM of Williams et al. In the cognitive-motivational model, the GES operates in a default mode where it assumes safety. Here, positive stimuli are prioritised and negative stimuli ignored. The GES will, however, interrupt current goals to orient resources toward stimuli evaluated as threatening by the VES. According to Mogg and Bradley there is a positive relationship between VES sensitivity and trait-anxiety.

In an impressive meta-analysis of threat-related attentional bias in anxiety, Bar-Haim et al. (2007) propose that, while their findings offer partial support for the models of both Williams et al. (1988, 1997) and Mogg and Bradley (1998), they also strongly challenge some of the outcomes predicted by these. For instance, Bar-Haim et al. suggest that the claim by Williams et al. that individuals low in trait-anxiety show a bias away from threat is, at best, very weak. Indeed, the findings of a number of more recent and specific studies (e.g., Derryberry & Reed, 2002; Koster, Crombez, Verschuere, & De Houwer, 2004; Koster, Crombez, Verschuere, & De Houwer, 2006) have indicated that the major contributor in this threat-related bias is slower attentional disengagement, rather than initial orienting (Bar-Haim et al., 2007; Derakshan, Ansari, Hansard, Shoker, & Eysenck, 2009).

Bar-Haim et al. (2007) also suggest that the larger effect size for consciously perceived threat-related stimuli, compared to those subliminally exposed, implicate both preattentive and postattentive mechanisms of resource allocation. They also argue for the separability of unconscious and conscious threat processing by demonstrating that stimulus awareness affects bias in opposite directions in dot-probe compared with emotional Stroop tasks. A model proposed by Mathews and Mackintosh (1998) is more in line with the assertions of Bar-Haim et al. that the evidence indicates that valence-based bias in anxiety involves preattentive, attentional, and postattentive processes.

The model of Mathews and Mackintosh (1998) is based on a competitive activation network. Here, a *threat-evaluation system* (similar to the ADM of Williams et al. 1988, 1997, and the VES of Mogg and Bradley, 1998) facilitates activation of stimuli weighted according to threat potential. Greater activation occurs in individuals with higher trait-anxiety, resulting in more preference in the competition for selection. This model also includes an element of attentional control through a *task demand* component that can

facilitate activation of any competing item within the network. This task demand component clearly represents a top-down operation that can be guided by task requirements or contextual factors.

Compton (2003), in her review of the literature pertaining to the relationship between emotion and attention, concludes that the evidence indicates a two-stage process. First, emotional significance is evaluated pre-attentively by a subcortical circuit involving the amygdale; and second, stimuli deemed emotionally significant are given priority in the competition for access to selective attention. Compton suggests that the emotional value of a stimulus appears to be encoded very early in the processing stream, within the first 100-300 milliseconds of stimulus onset.

The early encoding of emotional information is supported by the work of Pizzagalli, Regard, and Lehmann (1999), who recorded ERPs in response to laterally presented faces that participants either liked or disliked. Their results indicated that liked and disliked faces produced ERPs that were distinguishable from one another as early as 80 to 160 milliseconds post stimulus onset. Further, Sato, Kochiyama, Yoshikawa, and Matsumura (2001) found that facial expression of both fear and happiness elicited greater negative-going amplitudes than neutral expressions at around 270ms post-stimulus.

More recently, Bar-Haim et al. (2005) have found evidence of differential processing of emotion information according to trait-anxiety status. Bar-Haim et al. used a spatial-cuing paradigm to investigate the allocation of attention by high and low trait-anxious participants. Cues were human face stimuli varying in emotion expression (angry, fearful, happy, neutral, and sad). The high trait-anxious group showed consistently slower response times to targets, regardless of cue valence. Bar-Haim et al. attributed this to increased processing of the cue, based on the work of Muller, Teder-Salejarvi, and Hillyard (1998) and Ward, Duncan, and Shapiro (1996), that has demonstrated how attentional resource allocation to an object can produce relatively persistent proactive interference when attempting to identify subsequent objects. Specific to the early encoding of emotion, Bar-Haim et al. found that, relative to the low trait-anxious group, high trait-anxious participants showed shorter P1 and N1 latencies over posterior sites and larger P2 amplitudes to angry faces at central sites.

Compton (2003) and Sato et al. (2001) attribute the rapidity of emotion discrimination to the sensitivity of the amygdalae to sensory-perceptual representations of emotionally salient stimuli. The amygdale is able to influence the allocation of attention through connection with other areas of the brain. Compton proposes the importance of two particular areas of the prefrontal cortices: the dorso-lateral prefrontal cortex (DLPFC) and the ventro-medial prefrontal cortex (VMPFC). The DLPFC is thought to be responsible for the maintenance of the attentional set, which provides guidance for the focus of attention on salient information. The VMPFC shares reciprocal connections with the amygdale (Groenewegen & Uylings, 2000), which provides capacity for top-down influence of the latter. Compton emphasises the functionality of top-down control for the selection or suppression of emotionally relevant information according to contextual demands.

Although Compton (2003) does not state this, given her modelling, it is conceivable that higher-order strategies for the management of emotion can exert top-down influence on the allocation of attention to emotionally relevant material. This could happen in a direct fashion, through the access to attentional focus via strength of attentional set maintenance occurring in the DLPFC. Alternatively, or in concert, this might also occur indirectly, through VMPFC modulation of activity in the amygdale. Regardless of whether this is indeed the case, or of the actual structures and mechanisms involved, it is nevertheless clear that both top-down and bottom up input can be influential in the allocation of attentional resources (Yiend, 2010).

The cooperation, or competition, of bottom-up and top-down processing is the foundation of the model proposed by Eysenck et al. (2007). Building on Eysenck's (1992) *Processing Efficiency Theory*, Eysenck et al. propose *Attentional Control Theory*, which they explicitly state as relative only to the context of anxiety and cognitive performance. Their central tenet is that anxiety reduces processing efficiency because it disrupts the balance between the bottom-up and top-down attentional systems. Specifically, it is associated with a reduction in the influence of the goal-directed attentional system and a concomitant increase in the influence of the stimulus-driven attentional system. This is said to result in reduced attentional control, which impairs inhibition and shifting functions.

In Attentional Control Theory, Eysenck et al. (2007) retain a crucial assumption of Processing Efficiency Theory – that anxiety impairs processing efficiency more than it does performance effectiveness. Further, they introduce a new assumption – that anxiety impairs attentional control regardless of the presence of threat-related or task-irrelevant stimuli. Eysenck et al. explain that it is potentially dangerous for a person to maintain strong attentional fixation on a specific stimulus or location if that person perceives themselves to be under threat. Here, they argue that a wide allocation of attentional resources would be an optimal strategy, which would reduce attentional control required for the performance of any concomitant task.

Derakshan et al. (2009) have provided evidence in support of the proposition by Eysenck et al. (2007) that anxiety impairs attentional control regardless of the presence of threat-related or task-irrelevant stimuli. Using a neutrally valenced antisaccade task, Derakshan et al. found an effect where high trait-anxious participants showed longer correct antisaccade latencies than low trait-anxious participants. Given that longer antisaccade latencies are considered to reflect the use of additional resources to inhibit the reflexive prosaccade (Olk & Kingstone, 2003), Derakshan et al. proposed this finding as evidence of a relative deficiency in attentional control for individuals with high trait-anxiety, independent of the presence of potential threat.

A study reported by Derryberry and Reed (2002) has also implicated attentional control deficiency in high trait-anxiety, independent of threat. Derryberry and Reed investigated the effect of trait anxiety and attentional control (as rated according to their Attentional Control Scale) on the regulation of the posterior orienting system by the anterior attention system. Using a spatial cuing paradigm, they found that high trait-anxious individuals who were rated as low in attentional control showed slower disengagement then those rated as high in attentional control, though only when the cue-target interval was 500ms. There were no differences between the groups when the cue-target interval was 250ms. These effects were found in the absence of emotionality within the tasks.

Derryberry and Reed (2002) interpreted their results as being consistent with Beck and Clark's (1997) three-stage model of information processing in anxiety. Beck and Clark propose that, upon registration of threat in the initial stage, a primal threat mode is

automatically activated. This is a preparatory stage concerned with primary threat appraisal. In the final stage, this primary appraisal gives way to secondary appraisals concerned with more elaborate processing of peripheral information relating to response.

The primary and secondary stages of threat appraisal proposed by Beck and Clark (1997), and supported by the findings of Derryberry and Reed (2002), share similarity with those of Compton (2003), discussed previously. Although there is an overlap in the time frame suggested for the earlier stage, for Compton, the processing that takes place there is entirely preconscious. Nevertheless, both models suggest that bottom-up input to the amygdale results in an automatic grip on attention, which requires resting in order for higher order processes to appraise broader information relating to management. For Compton, this disruption of balance between bottom-up and top-down attention systems impairs anterior control of the posterior orienting system, which is consistent with Beck and Clark's first and second stages. Further, Compton's assertion is also consistent with the account proposed in Attentional Control Theory (Eysenck et al, 2007), where increased influence of the stimulus-driven attentional system reduces regulatory control of the goal-directed attentional system over inhibition and shifting functions.

There is solid empirical support for the respective concordance among the theories posited by Beck and Clark (1997), Compton (2003) and Eysenck et al. (2007) around the interference of automatic threat appraisal process on executive control of attentional orienting mechanisms. As cited earlier, a number of studies have implicated slowed disengagement in trait-anxiety (e.g., Derryberry & Reed, 2002; Koster et al., 2004; Koster et al., 2006). What remains unclear however, are the contributions of engagement facilitation and disengagement suppression (Derryberry & Reed, 2002). Whatever the case, the evidence indicates that trait-anxiety can impair attentional control, regardless of exogenous threat.

The notion of a relationship between a personality trait, such as anxiety-proneness, and a characteristic pattern of cognitive processing, is self-evident. It has been established in the present chapter that trait-anxiety is associated with the operation of early, unconscious, evaluative processes involved in selective attention. As discussed in Chapter 3, selective attention is a strategic operation that functions to facilitate effective use of processing resources. Given the robust detrimental effect of threat-perception on

processing efficiency in high trait-anxiety, the development of compensatory strategies is not improbable. The apparent flexibility of preconscious selective attentional processes may provide an opportunity for the suppression from consciousness of threat-related information, thought to operate in repression.

Repression, Anxiety and Attention

As discussed in Chapter 2, repression is a psychological defence strategy where the experience of negative emotional states associated with anxiety are avoided through the deflection of personally threatening information from consciousness (Derakshan et al., 2007; Freud, 1915/1957; Furnham et al., 2003). Repressive coping style is characterised by the exhibition of high levels of anxiety on non-verbal measures despite low self-reported anxiety. In psychological research, individuals reporting both low trait-anxiety and high psychological defensiveness are classified as repressors (Derakshan et al., 2007).

In the previous section, evidence was presented demonstrating differences between high and low trait-anxiety in the operation of early, unconscious, evaluative processes involved in selective attention. Further, it was established that the flexibility of preconscious selective attentional processes is sufficient to allow strategic management of specific information. Finally, it was suggested that repressors strategically exploit this flexibility to avoid experiencing negative emotion states associated with anxiety through preconscious suppression of threat-related information. The primary focus of the remainder of the present chapter is the presentation of theory and evidence relating to the process of repression.

Evidence of discordance between repressors' low levels of self-report anxiety, and that indexed by psychophysiological, behavioural, and hormonal measures has been well established (see Derakshan et al., 2007; Schwerdtfeger & Kohlmann, 2004; and Weinberger, 1990, for reviews). Further, a number of studies have demonstrated the authenticity of repressors' claims of low levels of experiential anxiety under stressful conditions (Derakshan & Eysenck, 1998; 1999; Weinberger, 1990). The findings of Derakshan and Eysenck (2005) suggest this may be achieved, at least partially, through attentional bias away from their internal state.

Another information processing factor thought to contribute to repressors' buffered conscious experience of anxiety is through interpretive bias. Eysenck (1997) proposed that repressors employ a bias for less-threatening interpretation of ambiguous information. He contrasted this to the threat-laden bias for ambiguous information observed in high trait-anxious individuals (see Eysenck, 1992, 1997, for reviews). Eysenck termed the contrasting interpretive styles of repressors and the high trait-anxious as *opposite interpretive bias*, stipulating that the truly low trait-anxious are characterised by the absence of any such bias. Although there have been a number of findings supporting this benign interpretive bias in repressors (e.g., Caldwell & Newman, 2005, Calvo & Eysenck, 2000; Derakshan & Eysenck, 1997; Lambie & Baker, 2003; McKinney & Newman, 2002) all of these involve, and occur following, lexical analysis.

As Calvo and Eysenck (2000) point out, for repression to occur threat-related information must be processed at some point in the processing stream. The time course of this, however, is quite unclear. While it is possible that such higher-order processing may operate quite late in the stream, in parallel with consciousness, the evidence for the relatively early encoding and attention to emotional information from trait-anxiety studies provides the more appealing prospect.

Calvo and Eysenck (2000) investigated the time course of the interpretive processing bias involved in repressive coping style through a series of experiments. These involved participants making speeded responses to outcome words completing context sentences that were either predictive of threat, or not. They found that repressors produced faster response times to words confirming threat outcomes at a delay of 550ms, whereas the high trait-anxious group were fastest when the delay was 1050ms. Calvo and Eysenck interpreted these findings as consistent with Eysenck's (1997) opposite interpretive bias, mentioned above. Further, they proposed that repressors engaged in a vigilance-avoidance operation, where threat processing is facilitated in the early stages, and inhibited at later stages. Finally, they suggested that high trait-anxiety was characterised by sustained vigilance.

Derakshan et al. (2007) elaborated on Calvo and Eysenck's (2000) interpretation in their articulation of Vigilance-Avoidance Theory. Essentially, Vigilance-Avoidance

Theory is a two-stage model. In the vigilance stage, repressors are said to employ an early attentional and interpretive bias for information interpretable as signifying potential threat. In the avoidance stage, self-relevant threat information deemed dismissible (though how this is done is not articulated) is diverted from conscious awareness through 'controlled and strategic processes' – perhaps tagged for inhibition. Derakshan et al. relate these stages to Brewin's (1996, as cited in Derakshan et al., 2007) distinction of situational knowledge that is primarily accessible preconsciously, and consciously accessible knowledge that is more verbal in nature. The other major assumption proposed by Derakshan et al. is that repressors can apply these avoidant processes not only to external stimuli, but also to internal events such as their own physiology and emotion-related cognitions.

Evidence consistent with a vigilance-avoidance model can be found in the results of a number of studies. For instance, Hock and Egloff (1998) conducted an experiment in which participants initially performed a lexical-decision task that included affective priming. This was followed by an unexpected recognition-memory test for some of the target words from the previous task. Repressors showed enhanced performance for threat-related words on the lexical decision task, and relatively poor recognition for threat-related words on the memory task. While the efficacy of a lexical-decision task for assessing vigilance is debatable, it can be argued that Hock and Egloff's results fit a profile of rapid vigilance toward processing of threat-related information, followed by avoidance, as indexed by subsequent poor memory for this (Derakshan et al., 2007).

A particularly eloquent illustration of the cognitive dynamics subserving repressive coping style was provided by Bonanno, Davis, Singer, and Schwartz (1991), by way of a dichotic listening task. Participants were presented affectively neutral or negative words to their unattended ear while they repeated aloud words presented in the attended ear. Participants also simultaneously performed a simple visual-probe task. Bonanno et al. reported that repressors made significantly fewer shadowing errors than the high trait-anxious participants, and marginally ($p<.10$) significantly fewer shadowing errors than low anxious participants, for both neutral and negative words. High anxious participants were found to have recognition for negative words presented to the unattended ear well above chance levels. There was no such effect for repressors and low trait-anxious

participants. Bonanno et al. surmised that repressors' ability to avoid or attenuate the processing of unwanted information made them particularly adept at maintaining attentional focus away from material they wish to ignore.

The findings of Bonanno et al. (1991) indicate that repressors possess an enhanced ability to inhibit attentional shift toward task irrelevant information. This may be equated with reduced distractibility, and similarly, attentional control. The findings of Bonanno et al. are supported by those of Broomfield and Turpin (2005). Using a spatial cueing paradigm comprising threat and non-threat words, Broomfield and Turpin found that repressors made fewer uninstructed eye movements toward threatening stimuli. This result is consistent with the avoidance of threat proposed in Vigilance-Avoidance Theory (Derakshan et al., 2007).

The function of inhibition in repressive coping style has also been investigated through the emotional Stroop paradigm. In this paradigm, slower colour-naming of threat-related words, compared to neutral words, is considered evidence of greater attentional engagement for threat (Derakshan et al., 2007). The most robust findings occur for repressors' successful inhibition of social-threat words, rather then physical-threat words (e.g., Mogg et al., 2000; Myers & McKenna, 1996; Newman & McKinney, 2002). This effect of greater avoidance for social-threat words has also been observed in dot-probe experiments (e.g., Fox, 1993; Mogg et al., 2000). These findings support the proposition of Mogg et al., that repression is more effective on information that is less immediately life-threatening; and are consistent with Mathews and Mackintosh's (1998) theory of activation for selection according to threat potential.

The evidence presented to this point corroborates the two primary assumptions on which repressive coping style is based. These are that, repressors show biases indicating that they are avoidant of threatening material, and that these avoidant processes are precipitated by preconscious attentional operations. More specifically, the evidence indicates that repressors show enhanced sensitivity to the processing of threatening stimuli but use efficient top-down control mechanisms to regulate the effects of these stimuli. When taken together, this evidence provides strong support for a vigilance-avoidance (Derakshan et al., 2007) explanation of repressive coping style.

The evidence-based theory for both repressive coping style and trait-anxiety is dominated by the theme of a sequential stage model involving preconscious appraisal of information toward selection for conscious management. Repressors and high trait-anxious individuals appear to differ in the strategic operations undertaken to conduct these processes. Repressors show a tendency to attenuate and dismiss potentially threatening information, whereas high trait-anxious individuals show a tendency for amplification and focus. Importantly, these differences have been shown to occur on tasks that involve no threat-related stimuli, suggesting that the underlying strategic processes operate independently of immediate exogenous danger.

The unconscious engagement of cognitive mechanisms toward more effective function is well established in cognitive psychology. In the context of human evolution, an overactive threat-detection system makes sense; as does the development of strategies to improve processing efficiency. Given this, a tendency to disregard or minimise unpleasant events may be advantageous in two ways. First, it may assist in the maintenance of attention on current goals by blocking prospective task-irrelevant negative distractors. Second, it would likely facilitate mood regulation through the reduction of negative input to consciousness (Eysenck et al., 2007; Mogg et al., 2000). Hence, the concept of a repressive coping style is compelling.

Chapter 6: Rationale and Aim

The aim of the present chapter is to articulate the overarching rationale and aims of the current dissertation. This will begin with a synthesis of the information presented to this point (particularly that contained in Chapter 5) toward formulation of the rationale for the current project. This will involve brief introduction of the experimental paradigms employed and culminate in a statement of the general aims. The intricacies involved in addressing the research question(s) will be developed through the experimental chapters, to follow.

As stated in Chapter 2, selective attention is crucial to the execution of goal-directed behaviour. It requires the strategic focussing of a limited pool of processing resources on goal-relevant information while actively suppressing processing of goal-irrelevant information (Lavie et al., 2004; Leung et al., 2000). Despite the lack of certainty concerning the complexities of selective attentional processing, the understanding of some of the fundamental component processes involved has been assisted by neuroscientific modelling. The most influential of these is the attentional orienting model proposed by Posner and Petersen (1990). This comprises the mechanisms of attentional disengagement, shifting, and engagement. The compelling nature of Posner and Petersen's model has seen other researchers extend it from the original visual domain to a broader, generalised, modality-free model of attentional orienting (Yiend, 2010).

The relationships between the mechanisms of disengagement, shifting, and engagement require cooperative dynamic attunement to allow the flexibility needed for adequate operation. This extends to the management of attentional resources for allocation to both bottom-up and top-down processing according to the goals of the agent and the demands of the operating environment. This is perhaps central to the concept of attentional control. The primary components of interest for the current thesis (given the topic of anxiety and attentional processes) are the basics of: shifting, focussing, and disengagement (stickiness v distractibility). The necessary flexibility inherent in functional attention allows for the component processes to cooperate in different ways.

Different personality styles entail different cognitive processing styles, and there is strong evidence of variation in the psychological management of information interpretable as signifying potential threat. Individuals with high levels of trait-anxiety have been shown to show an attentional bias for threatening stimuli or events. This appears more related to a relative difficulty with disengaging attention from sources of potential threat, rather than a greater attraction to it, per se. Individuals low in trait-anxiety do not exhibit such a bias. There is also evidence that high trait-anxiety impairs attentional control regardless of the presence of threat-related or task-irrelevant stimuli. This can be explained in terms of an adaptive mechanism inhibiting strong attentional fixation on anything under circumstances where a person perceives themselves to be under threat. This suggests that individuals with high trait-anxiety may have a relative deficiency in attentional control (for reviews, see: Eysenck, 1992; Mathews & MacLeod, 1994; Williams et al., 1996).

Given the robust effect for a particularly detrimental effect of threat-perception on processing efficiency in high trait-anxiety, the development of functional compensatory strategies would appear adaptive. A third group, who report low trait anxiety, but show high anxious reactivity, have been identified as employing a repressive coping style. The demonstrated flexibility of preconscious selective attentional processes provides opportunity for the suppression from consciousness of threat-related information, thought to operate in repression. The two primary tenets of repressive coping style are that repressors show biases indicating that they are avoidant of threatening material, and that these avoidant processes are found with both external and internal stimuli (for reviews, see: Derakshan et al., 2007; Schwerdtfeger & Kohlmann, 2004; and Weinberger, 1990).

The evidence suggests that repressors engage in a vigilance-avoidance style of appraisal. Here, it appears that stimuli and events are pre-attentively scanned for sources of potential threat, which are then quarantined from conscious experience. The capacity for individuals to repress their experience of anxiety in this way has implications for the understanding of selective attentional processes. It suggests the operation of a process where the emotional significance is evaluated pre-attentively with stimuli deemed

emotionally significant given priority, or not, in the competition for access to selective attention.

ERPs provide unparalleled information toward the elucidation of the processes involved in selective attention, particularly when investigating the rapid, fine, earlier processes in stimulus appraisal. Hence, ERPs can provide indices of the earlier, more stimulus driven bottom-up processes, as well as the later more top-down processes, that behavioural measures cannot (Ilan & Polich, 2001). The investigation of potential differences in attentional processes employed by high and low trait-anxious individuals, and individuals who use a repressive coping style not only require tasks that necessitate clear engagement of selective attention, but also an index that can measure the timing and effort invested in very rapidly occurring and changing processes.

All of the attentional mechanisms of theoretical interest can be investigated through the application of a divided attention task, a switching task, and an interference task. Dual tasks can provide a clear indication of attentional resource allocation through the clear division of task requirements. They also require the shifting of attentional focus between tasks. Switching tasks require flexibility to shift between mental response sets, and Stroop tasks require inhibition of prepotent responses. The employment of these tasks provides coverage of the constructs of flexibility, distractibility, disengagement, shifting, and inhibition from different aspects.

The aim of the present thesis was to investigate whether the operation of attentional mechanisms differs in people according to variation in trait-anxiety, or repressive coping style. The investigation was constrained to the way individuals with sub-clinical levels of anxiety may differ in their basic attentional processing under conditions of neutral valence. Event-related potentials were employed as a means of investigating subtle differences in the way these attributes affect the processing carried out through these mechanisms. Although several theories are presented throughout this work, this is done for the purpose of information only; it is not the aim of the present thesis to test any of these directly.

Chapter 7: Stroop Interference

Introduction

The broader scope of the current thesis concerns the prospect of differential selective attentional processing between individuals classified as either, Low Trait-Anxious, High Trait-Anxious, or Repressors in an emotionally neutral context. As discussed in Chapter 3, selective attention is considered to comprise three component processes: disengagement, shifting, and engagement. Within this context, the primary aim of the present experiment was to investigate inhibition of attention as a strategic function of the disengagement sub-component of selective attention.

Toward this aim, a classic Stroop colour-word interference task was employed. This paradigm is well suited to the current purpose, as it requires the inhibition of attention to a task-irrelevant stimulus attribute, to which attention is biased, in order to process the task-relevant attribute of the stimulus. In addition to the classic performance indices of response time and accuracy, ERPs were employed to provide metrics of cognitive resource allocation, as behavioural measures are less sensitive to the subtle processing involved in these operations.

The Stroop Interference Paradigm

The role of selective attention in processing task-relevant stimuli over task-irrelevant stimuli, toward the execution of task-relevant responses, is crucial. The investigation of selective attention therefore requires the employment of tasks that produce cognitive interference, or competing information processing demands (Leung et al., 2000). The Stroop interference paradigm (Stroop, 1935) is the most extensively studied selective attention paradigm in cognitive psychology (Ilan & Polich, 2001; Leung et al., 2000; Liotti et al., 2000). The essence of this paradigm is the conflict between an automatic behaviour, such as reading, and a decision task that requires the inhibition of processes triggered by the automatic behaviour (Leung et al., 2000).

The increased response latency observed when people are required to name the presentation colour of a word that names an incongruent colour (e.g., the word “blue”

printed in green ink) was first described by Stroop in 1935. Commonly referred to as Stroop interference, the robustness of this effect is well established (see MacLeod, 1991, for a review). Stroop interference provides an index of the degree to which participants are unable to ignore irrelevant stimulus information (i.e., word meaning), with smaller interference effects indicating superior selective attention to relevant stimulus information (i.e., presentation colour) (Ilan & Polich, 2001).

Despite over 70 years of research into the phenomenon, the processes involved in Stroop interference remain relatively unclear (Hanslmayr et al., 2008), with ongoing debate as to how the interference affects the processing stream (Atkinson, Drysdale, & Fulham, 2003). Some researchers (e.g., Atkinson et al., 2003; Liotti et al., 2000) support a *race* model (Morton & Chambers, 1973), where both relevant and irrelevant stimulus attributes are processed in parallel. In the race model, interference is argued to be the product of response conflict resulting from the irrelevant stimulus attribute (word meaning) being processed faster than the relevant stimulus attribute (colour), resulting in earlier availability of the task-inconsistent response (Liotti et al., 2000). Other researchers (e.g., Magen & Cohen, 2002) posit the operation of an earlier task-guided input selection mechanism, as well as a later conflict resolution operation.

Anxiety and Stroop Interference

The automaticity of word reading in the classic colour-word Stroop paradigm has also allowed researchers to investigate attentional control in emotional contexts. An 'emotional' Stroop paradigm is achieved through the inclusion of emotionally evocative words (see Williams, Mathews, & MacLeod, 1996, for a review). Emotional Stroop tasks using threat-related words have been used to investigate attentional processing biases in populations varying in degree of trait-anxiety, as well as repressors. The assumption underpinning this methodology is that attentional bias toward threat should slow down colour-naming, whereas avoidant attentional bias should not. Further, the operation of an avoidant attentional bias is considered capable of facilitating colour-naming (Derakshan, Eysenck, & Myers, 2007).

The effect of delayed colour-naming of threat-related stimuli by individuals high in trait-anxiety relative to those low in trait-anxiety has been replicated in a number of

studies (e.g., Becker, Rinck, Margraf, & Roth, 2001; Mogg, Bradley, Williams, & Matthews, 1993; Mogg, Bradley, Dixon, Fisher, Twelftree, & McWilliams, 2000; Williams et al., 1996). While these findings support the established threat-related attentional bias associated with trait-anxiety, other findings have provided evidence of an opposite attentional bias for repressors. At least three studies using emotional Stroop paradigms have found repressors to be superior to non-repressors in inhibiting attention to threatening material. These are summarised directly below.

Mogg et al. (2000) compared the performances of low trait-anxious, high trait-anxious and repressor groups in an emotional Stroop paradigm. Their task included both social and physical threat words, along with control words. Not surprisingly, interference caused by threat-related words was found to be greatest for the high trait-anxious group. This effect is consistent with the predictions of the Attention Control Theory proposed by Eysenck et al. (2007), presented in Chapter 5. The repressor group, however, was shown to experience less interference when processing threat-related words than control words. This apparent facilitation of processing enjoyed by repressors is consistent with the Vigilance-Avoidance Theory of Derakshan et al. (2007), also presented in Chapter 5.

Myers and McKenna (1996) also employed words representing social threat in their emotional Stroop task. Although they did not find differences between their high and low trait-anxious groups, both of these groups showed delayed colour-naming for threat words, whereas the repressor group did not. Similar results were reported by Newman and McKinney (2002), who presented participants with social-threat words specifically threatening to each individual. While, overall, they found colour naming to be much slower to threat words than to control words, repressors were found to colour-name threat words as rapidly as control words.

Overall, these findings indicate a pattern of bias when processing threat-related words. Specifically, individuals high in trait-anxiety appear more susceptible to interference than those low in trait-anxiety, whereas repressors appear somewhat impervious to the interference. Indeed, threat-related words have been shown to have a converse effect on repressors, whereby colour-naming is facilitated. This pattern suggests differences in the manner in which these groups process task-irrelevant threat-

related material. Whereas both low and high trait-anxious individuals appear to experience distraction, low trait-anxious individuals are better able to moderate this and apply resources to the relevant task. Repressors apparent ability to avoid such distraction suggests they possess a superior capability for the inhibition of threat-related material than either low or high trait-anxious individuals, especially the latter.

These findings are consistent with Vigilance-Avoidance Theory (Derakshan et al., 2007) in the case of repressors and Attentional Control Theory (Eysenck et al., 2007) with regard to the inverse relationship between anxiety and processing efficiency. What remains to be seen, however, is whether these characteristic attentional processing patterns operate in neutrally valenced contexts. If, as discussed in Chapters 5 and 6, threat-vigilance is a fundamental element of both trait-anxiety and repression, then it must always be *en garde*. This is consistent with one of the assumptions of Attentional Control Theory; that anxiety impairs attentional control regardless of the presence of apparent threat. Further, however, if these respective characteristic patterns of attentional processing operate more or less constantly, then it would be expected that they should become habitual, and manifest regardless of context. This proposition is central to the present thesis.

Stroop Interference and ERPs

The capacity to provide information on the intensity of cognitive processes with millisecond precision makes ERPs an obvious choice for the elucidation of the processes involved in Stroop interference (Ilan & Polich, 2001; Thomas, Johnstone, & Gonsalvez, 2006). Given this, it is disappointing that existing literature involving ERP investigation of the Stroop paradigm is not richer or more conclusive. Many of those studies that are available have focussed on effects involving later negative-going activity, likened to N4 (Hanslmayr et al., 2008; Kutas & Hillyard, 1980), that are typical of ERP studies using the Stroop colour interference task (e.g., Cohen et al., 1988; Duncan-Johnson & Kopell, 1981; Hanslmayr et al., 2008; Ilan & Polich, 1999; Kutas & Hillyard, 1980; Liotti et al., 2000; Posner & Raichle, 1994; Rebai, Bernard, & Lannou, 1997; Rosenfeld & Skogsberg, 2006; West, 2003; West & Alain, 1999). While this focus has improved the understanding of the later-stage response conflict aspects of Stroop interference, the

earlier-stage attention-related aspects have remained largely neglected. Moreover, much of the existing research focuses solely on Stroop interference in emotional paradigms. Hence, there is little research evidence relating to earlier-stage ERP correlates in classic Stroop colour-word interference, leaving the area poorly understood. In addition to the paucity of research into ERP correlates in classic colour-word Stroop interference, of those that have, none have examined the roles of trait-anxiety or repression. As the attentional processing associated with these constructs is central to the present thesis, this void should be addressed.

Of those studies that have investigated the role of earlier-stage ERP components in classic colour-word Stroop interference, the earliest of these were constrained to the investigation of P3 latency. Both Duncan-Johnson and Kopell (1981) and Ilan and Polich (1999) reported no reliable effects, surmising P3 to be insensitive to Stroop interference. In a later, more comprehensive study, Ilan and Polich (2001) found P3 amplitudes to be lower in response to neutral words than either incongruent or congruent words. Further, and somewhat peculiarly, they found the associated latencies to be longer, rather than shorter, in the neutral condition compared to the incongruent or congruent conditions. The authors attributed this latency effect to the use of infrequent words in the neutral condition. Ilan and Polich also analysed amplitude and latency data for the N1, P2, and N2 components, though found no significant results.

Other research into the effect of classic Stroop interference on a range of ERP components has also been conducted. Many of these, however, have employed methodological approaches that compromise fundamental processes in the paradigm, as it relates to the present thesis (e.g., oddball paradigm used by Rosenfeld & Skogsberg, 2006). As such, these studies have not been discussed in the present work. There are, however, at least three studies that have employed ERPs to investigate the effects of threat-related words using the Stroop paradigm. Metzger, Orr, Lasko, McNally, and Pitman (1997) used P3 amplitude and latency to investigate the effects of posttraumatic stress disorder (PTSD) on emotional Stroop interference. Three word types were used: neutral, personally positive, and personally traumatic. Compared with the control group, the PTSD group were slower to name all word types. Further, the PTSD group produced lower P3 amplitudes, which peaked later, across all word types.

Pérez-Edgar and Fox (2003) investigated the effects of emotional Stroop interference on attentional processing in 11 year-old children. They found smaller N1 amplitudes to emotionally negative words, relative to positive and neutral words. The N2 component was also smaller to negative words than positive words, though not neutral words. Pérez-Edgar and Fox suggest these findings indicate the presence of latent attentional biases in early perceptual processing. These results should be considered with caution due to the neurodevelopmental level of the sample, and the absence of word category effects for either P3 or N4, the latter of which is uncommon in experiments using the classic Stroop paradigm.

Thomas et al. (2007) investigated whether normal adults showed enhanced attention to words they found personally threatening. Response times to neutral and threatening words were found not to differ. This was also the case for the latencies of each of the components they analysed: N1, P2, N2 and P3. Analysis of the amplitude data, however, showed both P2 and P3 to be larger in response to threat words than neutral words, though the former only in the right hemisphere (P4 electrode).

The above review presents an existing body of relevant research into earlier-stage ERP correlates in Stroop interference that is far from comprehensive. This unsatisfactory situation can be attributed to a number of factors. These include large variations in stimuli and task characteristics, experimental methodologies, inadequate sample sizes, and even ERP processing practices (Thomas et al., 2007; West & Alain, 1999). Whatever the reasons for the dearth of knowledge in this area, it remains that drawing inferences from the extant body of findings can be done with little confidence. Nevertheless, some tentative suggestions can be made. The most compelling of these is that the latencies of the earlier-stage components appear largely insensitive to Stroop interference. There is, however, evidence of sensitivity on the amplitude dimension of these components. This is most prevalent for P3 amplitude, having been shown to be higher during classic Stroop interference (Ilan & Polich, 2001), as well as when colour-naming threat-related words (Metzger et al., 1997; Thomas et al., 2007). Further, P2 has also been found to increase when colour-naming threat words (Thomas et al., 2007). Finally, N1 and N2 have been shown to decrease when children colour-name negative words (Pérez-Edgar et al., 2003).

In sum, there is some convergent evidence for P3 amplitude to increase as a function of Stroop interference. In addition, there have been isolated findings suggesting the sensitivity of earlier components. This, in concert with the lack of cohesive research in this area, indicates that there remains much to be learned about ERP correlates of Stroop interference.

Rationale

As discussed in Chapter 5, a strong body of research evidence exists indicating that individuals high in trait-anxiety exhibit slower disengagement from threat than those low in trait-anxiety (Becker et al., 2001; Mogg et al., 1993; Mogg et al., 2000; Williams et al., 1996). Repressors, on the other hand, have been found to show facilitated disengagement of attention from threat (Fox, 1993; Mogg et al., 2000; Myers & McKenna, 1996; Newman & McKinney, 2002). Hence, whereas high trait-anxiety can be characterised by sustained vigilance, repression is thought to operate through a vigilance-avoidance process, where early threat detection facilitates rapid inhibition, and thereby protection from consciousness (Calvo & Eysenck, 2000; Derakshan et al., 2007).

An assumption of Attentional Control Theory (Eysenck et al., 2007) is that, central to the current thesis, anxiety impairs attentional control regardless of the presence of threat-related or task-irrelevant stimuli. As reviewed in Chapter 5, both Derryberry and Reed (2002), and Derakshan et al. (2009) found evidence supporting this assumption using a spatial orienting task, and an antisaccade task, respectively. Unfortunately, however, neither of these studies included a repressor group. Further, both of these tasks involve a heavy qualitative emphasis on stimulus location, as opposed to stimulus features.

Understanding the relative differences in attentional processes employed as a function of trait-anxiety or repressor status not only requires a task that clearly distinguishes engagement of selective attention and the operation of inhibition, but also indexes the timing and effort invested in very rapidly occurring and changing processes. The Stroop colour-word interference task provides the former, and ERPs provide the latter. Unfortunately, however, current understanding of earlier-stage ERP correlates of Stroop interference remains poor. Improving this understanding requires an ERP study

of fundamental Stroop interference. As such, a secondary aim of the present experiment was to perform a study of earlier-stage ERP correlates in Stroop colour-word interference.

The current study therefore employed a classic Stroop colour-word task to investigate the prospect of differential selective attentional processing between individuals classified as either low trait-anxious, high trait-anxious, or repressors, in an emotionally neutral context. More specifically, the interest was in investigating characteristic degrees of operational flexibility in disengagement, shifting, and engagement subcomponents of selective attention (as detailed in Chapter 3). Within this context, the primary aim of the current experiment was to investigate the inhibition of attention as a function of the disengagement sub-component of selective attention using ERP metrics. An additional aim of the present experiment was to perform a study of ERP correlates in Stroop colour-word interference, against a true control condition.

Hypotheses

Performance Measures

Response Latency

In accordance with the large and consistent body of research findings (see MacLeod, 1991), participants' response latencies were predicted to be significantly longer when required to identify the presentation colour of words that name an incongruent colour, than when required to identify the presentation colour of control stimuli. That is, the classic Stroop interference effect. Given the stimuli used in the present experiment were ostensibly non-valent, response latency was not predicted to be sensitive to differential processing between groups. Nevertheless, should group differences emerge, the premier expectation would be for repressors to produce shorter response latencies than other groups on interference trials, due to their demonstrated superiority on the inhibition of task-irrelevant, threat-related, information in emotional Stroop tasks (e.g., Mogg et al., 2000; Myers & McKenna, 1996; Newman & McKinney, 2002).

Response Accuracy

Classic Stroop interference often involves poorer response accuracy compared to Stroop facilitation and/or control conditions (e.g., Hanslmayer et al., 2008; Liotti et al., 2000; West & Alain, 2000), though not always (e.g., Ilan & Polich, 2001). Hence, it was predicted that participants would make fewer errors when responding to trials in the control condition than to trials in the Stroop interference condition. Response accuracy was not expected to differ as a function of group.

ERP Measures

As mentioned previously, the existing research into the earlier ERP correlates in Stroop interference is scant, and the evidence inconclusive. This presents difficulties in formulating definitive hypotheses, particularly relating to the earlier of these components; namely N1, P2, N2. As such, all ERP-related hypotheses proposed in the present experiment are presented tentatively.

Amplitude

Two findings provide convergent evidence for enhanced P3 activity related to Stroop interference. These include Stroop interference in the classic form (Ilan & Polich, 2001) and in the form of threat-relevance (Thomas et al., 2007). As P3 is considered to index attentional resource allocation associated with conscious decision making processes, it was predicted that any effect involving P3 amplitude in the present experiment would be in the direction of larger P3 amplitudes in the interference condition than the control condition. In addition, given that repressors are presumed to achieve superior inhibition of task-irrelevant information, should P3 amplitude show sensitivity to any differences between groups, this would be expected to be lowest for repressors. Further, any difference between groups would be in the order of increasing as a function of trait-anxiety. As it has been well established that P3 is a parietal component, P3 analyses will be constrained to the Parietal site.

Similarly, analyses on N2 will be constrained to Fz, as it is the anterior subcomponent of N2 that is of interest to the present work. Whereas, posterior N2 is sensitive to probability and is considered to provide an index of resources allocated to

the processing of stimuli in the visual cortex, anterior N2 is believed to index conflict monitoring processes related to decisional or categorisation operations. Given this, repressors would be expected to show lower N2 amplitude to Stroop interference, owing to their presumed superiority at inhibition of task-irrelevant information. Further, as was the case with P3, any group differences would be expected to be in the order of increasing as a function of trait-anxiety.

Regarding the earlier components, N1 and P2, the scattering of isolated findings presented above provide little basis on which to form specific hypotheses. These findings do, however, suggest these components may be sensitive to Stroop interference. Given this prospective sensitivity, some tentative predictions are possible. Should repressors and high trait-anxious participants engage in enhanced early processing toward rapid threat detection, then this would be evidenced by amplitude modulation of earlier components; namely, of N1, which is considered to provide an index of attentional processes involved in early selection for further processing; and P2, which is thought to index resources allocated to processes associated with the facilitation of feature detection and stimulus discrimination.

Current understanding of the functional correlates of N1 and P2 are not nearly as well advanced as those for N2 and P3; including relationships between function and topography. For instance, in the visual modality, N1 is commonly detected at occipital, parietal, central, and frontal sites; whereas P2 shows distributions centring around fronto-central and occipito-parietal regions, and tends to be maximal at the vertex. As such, no prediction was made with reference to localisation of effects involving N1 and P2.

Latency

The most reliable finding is that the latencies of earlier-stage components appear largely insensitive to Stroop interference. As such, latency was not expected to be affected in the current experiment. Notwithstanding this, however, if repressors and high trait-anxious participants engage in enhanced early processing, then latency modulation of earlier-stage components for these groups would not be unexpected. Latency analyses

for each component will be constrained to the parameters specified for the amplitude analyses, above.

Method

Participants

Initially 441 female first-year psychology students and five female post-graduate psychology students completed the *Trait* version (Form Y-2) of Spielberger's (1983) *State-Trait Anxiety Inventory for Adults* (STAI-T), which remains the most used instrument for the assessment of trait-anxiety (Eysenck, 2000). Missing values were treated as per the *State-Trait Anxiety Inventory for Adults Manual* (STAI-AD Manual) (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). That is, where one or two items were not responded to, the mean of the participant's other responses was substituted. Where this resulted in a total score with a decimal fraction, the next highest number was taken as that respondent's score. Where three or more items were not responded to, that respondent's data was deemed unreliable and withdrawn.

In instances where two responses were made to a single item, if these were consecutive (e.g., 2 and 3), the mean value was taken as a valid response (e.g., 2.5); however, if the values were not consecutive (e.g., 2 and 4) then the item was treated as missing data. Where this averaging of scores resulted in a total score with a decimal fraction, the next highest number was taken as that respondent's score. Eight respondents failed to respond on one item, and one respondent did not respond to two items. Three respondents reported two values on one item, and two respondents reported two values on two items.

Following this treatment of the data, the sample of Initial Respondents comprised 446 females ranging from 16-61 years of age (M=20.50, SD=3.73). As it has been established that P3 amplitude and latency vary with age (Martin, Barajas, Fernandez, & Torres, 1988), only respondents between the ages of 18-35 years were deemed eligible to participate, and comprised the Participant Pool. The characteristics of characteristics of the Participant Pool can be seen in comparison to those of the subsequent

Experimental Participants, and normative samples from the STAI Manual (Spielberger, 1983) in Table 7.1.

Table 7.1
Comparison of Initial Respondents, Participant Pool, Experimental Participants, and normative samples on sample size and STAI-T score characteristics

Sample	N	STAI-T			
		Mean	SD	Minimum Score	Maximum Score
Initial Respondents	446	41.84	9.49	21	70
Participant Pool	391	41.63	9.62	21	70
Experiment Participants	69	39.17	11.16	23	70
Female University Students (STAI Manual)	481	40.40	10.15	n/a	n/a
Working Females Aged 19-39 (STAI Manual)	210	36.15	9.53	n/a	n/a

Note. The STAI (Form Y) Manual (Spielberger, 1983) provides normative data only for select samples, with data for males and females presented separately.

During the initial screening, respondents were asked to complete a Demographic Information form (see Appendix A) which asked their age, sex, whether they would consider participating in further research, and whether English was their first language. If English was not the respondent's first language they were asked to indicate whether their English language skills were a) better than their first language skills, b) equal to their first language skills, or c) not as good as their first language skills. In an effort to ensure that participants properly understood the STAI-T items respondents who reported that their English language skills were not as good as their first language skills were not considered for participation in the experiment.

Another constraint on consideration for participation was sex, with only females being included in the current experiment. There are three main reasons for this. First, the normative data presented in the STAI-AD Manual (Spielberger et al., 1983, p. 13) shows that on the STAI-T female college students females reported higher scores (*M*=40.40) with greater variance (*SD*=10.15) than males (*M*=38.30, *SD*=9.18). Second, males and females tend to show differences in hemispheric lateralisation, with males typically exhibiting higher asymmetry than females (Walla, Hufnagl, Lindinger, Deecke, & Lang, 2001), an important consideration in ERP studies. Finally, differences are often found between males and females in the amplitude and latency of several ERP components (e.g., Gölgeli, Süer, Özesmi, Açiogolu, & Sahin, 1999; Shen, 2005; Vaquero, Cardoso, Vázquez, & Gómez, 2004). Additionally, as it has been established that P3b amplitude and latency vary with age (Martin et al., 1988), only respondents between the ages of 17-35 years were deemed eligible for inclusion. Those respondents meeting all of the requirements outlined above comprised the *Participant Pool*, the characteristics of which are included in Table 7.1.

In order to achieve the required experimental groups, the 391 respondents who comprised the Participant Pool were allocated to one of five groups according to their STAI-T scores: *Low Anxious*, 21-35 (n=101); *Low-Medium Anxious*, 36-39 (n=68); *Medium Anxious*, 40-44 (n=76); *Medium-High Anxious*, 45-48 (n=53); and *High Anxious*, 49-70 (n=93). These five groups were created in order to provide greater distinction between the groups of experimental interest through disregarding respondents in the groups intermediating these; namely the Low-Medium and Medium-High groups. This process achieved separation of the Low Anxious, Medium Anxious, and High Anxious groups by more than the greatest standard deviation of any of the groups. Table 7.2 provides a clear demonstration of this, along with the characteristics of the Low, Medium and High Trait-Anxious participant pool groups in relation to those of the groups comprising the eventual experimental participants.

Table 7.2 also includes the characteristics of the experimental participants who comprised the Repressor group. Repressors were categorised according to an adaptation of the process used by Weinberger, Schwartz, and Davidson (1979). Although repressors have been identified using a number of systems, the combination of low trait-anxiety

and high psychological defensiveness used by Weinberger et al. remains the most influential (Derakshan et al., 2007).

Weinberger et al. (1979) identified repressors as those who scored 13 or below on the Manifest Anxiety Scale (Taylor, 1953), as well as 19 or above on the Marlowe-Crowne Social Desirability Scale (MCSDS; Crowne & Marlowe, 1960). This process has since been adapted, with more contemporary research typically maintaining the MCSDS and the cut-off score of 19, but substituting the STAI-T in place of the Manifest Anxiety Scale (e.g., Bar-Haim, Lamy & Glickman, 2005; Bromfield & Turpin, 2005; Calvo & Eysenck, 2000; Dawkins & Furnham, 1989; Derakshan & Eysenck, 2001; Fox, 1993; Fox, 1994). Hence, in the present experiment, those participants from the low in trait-anxiety pool who scored 19 or above on the MCSDS were subsequently classed repressors.

Table 7.2
Comparison of the Low, Medium and High Anxious prospective participant groups, and eventual experimental groups on sample size and STAI-T score characteristics

Sample	N	STAI-T			
		Mean	SD	Minimum Score	Maximum Score
High Pool	93	54.40	5.03	49	70
High Experimental	18	54.83	6.01	49	70
Medium-High Pool	53	46.53	1.12	45	48
Medium Pool	76	41.93	1.38	40	44
Med. Experimental	16	41.75	1.24	40	44
Low-Medium Pool	68	37.68	1.11	36	39
Low Pool	101	29.72	4.06	21	35
Low Experimental	23	30.44	2.29	25	35
Repressor Group	12	29.00	4.24	23	34

The experimental sample comprised 69 right-handed female psychology students from the University of Tasmania aged between 18 years, 2 months, and 33 years, 3 months (M = 20 years, 4 months, SD = 3 years, 2 months). Of these, 56 were first-year students who participated in exchange for partial course credit, eight were first-year students who were paid $30 for their time, with the remaining five being psychology post-graduate students volunteering their time.

One-way ANOVAs conducted on mean age and STAI-T scores showed that the experimental groups were not significantly different on mean age $F(3,65)=0.50$, MSE=1448, $p=.686$, however a significant main effect was found for total STAI-T score, $F(3,65)=171.27$, MSE=14.63, $p<.001$, $\eta^2=.888$. Tukey HSD post-hoc tests revealed that the mean STAI-T score for the High-Anxious group was significantly higher than that of the Medium-Anxious group, which was significantly higher than the mean total STAI-T score for the Low-Anxious and Repressor groups (ps<.05). The Low-Anxious and Repressor groups did not differ (ps>.05). These means and standard deviations are presented in Table 7.2.

Apparatus

Experimental tasks were presented on a 19-inch LED monitor via Neuroscan STIM 4.1 software. Participants either responded verbally, or by button press on a standard keyboard, depending on the task. Electroencephalographic (EEG) activity from 15 sites was collected by a 32 channel Electro-Cap Inc. electrode cap with sintered Ag/Ag Cl electrodes, according to the 10-20 system of electrode placement (Jasper, 1958). EEG data was recorded continuously using SynAmps 1 amplifiers and Neuroscan SCAN 4.3.1 software.

EEG Recording

EEG activity was sampled continuously at 1000Hz, with a high pass filter of 0.15Hz and a low pass filter of 100Hz. Continuous recordings were merged with behavioural data, corrected for vertical electroocular activity (VEOG), then band-pass filtered (0.15-30Hz at 48dB per octave). Correct responses were averaged for a 1000ms epoch commencing 100ms prior to stimulus onset, with those containing artefacts above

100μV and below -100μV being rejected. Epochs were corrected to pre-stimulus baseline levels. Toward minimising the impact of latency jitter on waveforms, a requirement for inclusion was that each averaged waveform contained a minimum number of epochs that represented no less than 67% of all trials presented for that condition (see Picton et al., 2000). No participant data were found to violate this standard. An anonymous examiner of the present dissertation requested inclusion of data on the number of trials for each experimental group in each condition. These are presented in Table 7.2.

Table 7.3
Comparison Across Groups on Numbers of Trials Included in ERP Waveforms for the Control and Interference Conditions (Numbers of Excluded Trials Appear in Parentheses).

Group	N	Control	Interference
Repressor	12	563 (13)	542 (34)
High Trait-Anxiety	18	827 (37)	816 (48)
Med. Trait-Anxiety	16	674 (46)	667 (53)
Low Trait-Anxiety	23	1039 (65)	996 (108)

Task and Stimuli

The present experiment used a Stroop colour-word task comprising 96 trials. Of these, 48 were interference trials and 48 were control trials. The characteristics of the stimuli employed are presented in Table 7.4. Each stimulus was presented four times in pseudorandom order, so that no stimulus colour dimension (letter string or colour) was presented consecutively. Letter strings were presented in 72 point Arial font for 2000ms. Stimulus onset, discretely controlled by the experimenter, was never less than 2000ms after the response to the previous stimulus, and typically varied between 2000-3000ms

post-response. Participants were required to simply name the colour in which each letter string was presented, as quickly and accurately as possible. Vocal response onset time was triggered via a microphone attached to a headset worn by participants. This procedure for measuring vocal response onset is similar to methodologies employed in other research using the Stroop paradigm (e.g., Duncan-Johnson & Kopell, 1981; Mogg et al., 1993; and Mogg et al., 2000). Response accuracy was recorded by the experimenter.

Table 7.4
Stroop and Control Stimuli Properties

Stroop Letter Strings	Stimulus Colour	Control Letter Strings
RED	Blue	XXX
RED	Green	XXX
RED	Yellow	XXX
BLUE	Red	XXXX
BLUE	Green	XXXX
BLUE	Yellow	XXXX
GREEN	Red	XXXXX
GREEN	Blue	XXXXX
GREEN	Yellow	XXXXX
YELLOW	Red	XXXXXX
YELLOW	Blue	XXXXXX
YELLOW	Green	XXXXXX

Note. Stroop and control stimuli, including colour and configuration, are similar to those employed by Rebai, Bernard, and Lannou (1997), West & Alain (2000), and West (2003).

Verbal response was favoured over the button-press modalities traditionally employed in Stroop paradigms using ERPs as a means of reducing interference associated with the increased response complexity required in the latter. The use of verbal responses in ERP methodologies is typically avoided as a matter of conservatism

based on the notion that muscle activity associated with speech compromises the validity of EEG data (Liotti et al., 2000; Rosenfeld & Skogsberg, 2006). Evidence contrary to this position can be found in the study by Liotti et al. (2000) on the temporal course of Stroop colour-word interference.

Liotti et al. (2000) collected behavioural and ERP data produced from overt and covert verbal response modalities, along with button presses. Whereas Liotti et al. employed two button-press conditions; the present discussion is constrained to the condition involving separate buttons for each of the four colours employed. Their Figure 7.1 (Top) provides a clear illustrative comparison of the overt and covert verbal, and button-press response modalities. This comparison shows relative concordance between overt verbal and button-press responses in the 0-200ms range at each of the included sites: FCz, Cz, Pzs and Pzi sites. At around 200ms, however, the profiles of the respective waveforms diverge, with differences becoming quite marked by 400ms. For instance, the magnitude of difference between consistent and inconsistent stimuli from approximately 400-600ms, at FCz, is much greater for the overt verbal response compared to manual response. Perhaps more importantly, parietal P3 to the overt verbal response appears to peak much earlier, and with concordantly much lower amplitude, than the manual response.

While Liotti et al. reported an absence of difference in response times for the overt verbal and button-press modalities, they did not report any accuracy data. Further, they did not report any direct comparison of ERP data between these response modalities. Hence, the affect of an extra stage of processing dedicated to organising the transformation of the essential decision into a choice of button depressions remains moot. Nevertheless, observation of the waveforms presented by Liotti et al. show no evidence that vocal response contaminates ERP data. Given this, and the likelihood that the essential processes involved in Stroop interference are less clearly represented when the orchestration of complex responses is required, a simple vocal response was employed in the present experiment.

Procedure

Prospective participants were contacted by telephone to discuss participation in the experiment. Those interested underwent a brief screening interview according to a standard ERP laboratory Medical and History Questionnaire (see Appendix B) and were not invited to participate if they were heavy smokers or binge drinkers, had recently used cannabis or other illicit substances, were on prescribed medications other than the contraceptive pill, or had previously suffered any mental or neurological illness or trauma as these factors have been documented as affecting the P3b component of the ERP (Polich & Kok, 1995). Further, to control for differences in P3b amplitude and topography between left- and right-handed people (Zillessen, Scheuerpflug, Fallgatter, Strik, & Warnke, 2001), including the hemispheric dominance of language function (Obleser, Rockstroh, & Eulitz, 2004), participants completed the Edinburgh Handedness Inventory (Oldfield, 1971), with only those achieving right-handed laterality (scores > 0) invited to continue. All participants had normal, or corrected to normal vision.

Participants attended the ERP lab at the University of Tasmania's Hobart Campus. After reading an information sheet (see Appendix C), participants signed a statement of informed consent (see Appendix D) in accordance with the approval (H8493) granted by the *Human Research Ethics (Tasmania) Network*. As psychoneurotic and depressed patients generally score highly on the STAI-T (Bieling, Antony, & Swinson, 1998; Spielberger et al., 1983), used here as the primary selection indicator, participants also completed the BDI-II (Beck, 1996). No participants' scores on the BDI-II were in the *Severe* range. All participants achieved perfect accuracy on an abbreviated version of Ishihara's Tests for Colour-Blindness (1917, as cited in Birch, 1997). Finally, all participants were deemed to be right-handed on completion of the Edinburgh Handedness Inventory.

Following this preliminary testing, participants' skin was prepared and an electrode cap fitted. Electrodes were attached to the outer canthi of each eye and above and below the left eye to monitor horizontal electroculographic (HEOG), and vertical electroculographic (VEOG) activity respectively. The AFz (ground) electrode was first filled with conducting gel, followed by the electrodes at sites F7, F3, Fz, F4, F8, T7, C3, Cz, C4, T8, P7, P3, Pz, P4, and P8 according to the 10-20 International system of

electrode placement (Jasper, 1958) and referenced to linked mastoids. All electrodes were then connected to the Neuroscan system and the impedance value of each checked, with only values below 5 kΩ being accepted.

Participants were then seated in a sound attenuated room at a distance of approximately 70cm from the monitor and given a general overview and demonstration of the task and response requirements. This was followed by a more specific instruction and practice session during which participants were required to demonstrate accurate colour perception for all experimental stimuli. The experimenter was present in the testing room, manually noting response accuracy and subsequently pressing a button to display the next stimulus in a discrete manner. The present experimental task (i.e., Stroop task) usually lasted no more than 10 minutes, which was approximately one fifth of experiment participation during the experimental session. It was conducted between the two task-switching paradigms (each with two conditions that ran between 6.5 to 7.0 minutes) that comprised the study presented in Chapter 8. No participants reported, or appeared to experience, adverse reactions to the experimental procedure.

Materials

Beck Depression Inventory – Second Edition (BDI-II; Beck, 1996)

The BDI-II is a 21-item unidimensional self-report instrument designed to assess the severity of symptoms corresponding to the criteria for diagnosis of depressive disorders in the American Psychiatric Association's (APA) *Diagnostic and Statistical Manual of Mental Disorders – Fourth Edition* (DSM-IV; APA, 1994). Although it was developed as an indicator of the presence and degree of depressive symptoms in adults and adolescents, the BDI-II is not designed to specify diagnosis. Each item comprises four statements (with the exception of Item 16, which has eight) that are rated on a four-point scale ranging from 0-3. Respondents select the statement that best describes the way they have been feeling in the past two weeks, with higher scores indicating greater symptom severity. The BDI-II typically takes between 5-10 minutes to complete. Information on the psychometric properties for non-patient samples is not as comprehensive as for patients, which are adequate (Beck, Steer, & Brown, 1996). Nevertheless, the classification ranges used for patients diagnosed with major depression

should be acceptable for the purposes of screening a non-patient sample. The internal consistency of the instrument is strong, with coefficient alphas of .92 and .93 reported in the BDI-II Manual (Beck, 1996) for outpatient and college student samples, respectively.

Edinburgh Handedness Inventory (Oldfield, 1971)

The Edinburgh Handedness Questionnaire comprises 10 forced-choice items that assess right or left hand dominance across a range of everyday activities. Responses contribute to a measurement scale that ranges from –100 for strong left-handedness, to +100 for strong right-handedness. The internal consistency of the instrument is strong, with reported coefficient alphas of .93 (Williams, 1991) and .96 (Chapman & Chapman, 1987). There have, however, been criticisms around several of the items (e.g., Dragovic, 2004; Milenkovic & Dragovic, 2012). These include colinearity between writing and drawing, and large measurement error associated with items relating to using a broom and opening a box-lid. Although these latter two items have been implicated in the misallocation of ambidexterity into hand-dominance, the instrument remains the most widely accepted in research.

Marlowe-Crowne Social Desirability Scale (MCSDS; Crowne & Marlowe, 1960)

The Marlowe-Crowne Social Desirability Scale is self-report questionnaire designed to provide an index of response bias relating to social desirability. It comprises 33 statements relating to behaviours considered to be regarded by society as exemplary, but only infrequently enacted. Respondents report whether these statements are either true or false of themselves, with higher scores suggestive of social desirability bias.

Although the MCSDS is the most commonly used assessment of social desirability bias, a number of studies have questioned its validity on both empirical and conceptual grounds (e.g., Barger, 2002; Leite & Beretvas, 2005). Whereas test-retest reliability of .89 at one month (Crowne & Marlow, 1960) is strong, the internal consistency has been shown to be less desirable, at .72 (Loo & Thorpe, 2000) and .75 (Loo & Loewen, 2004). Nevertheless, it has been shown to be useful, in conjunction with trait-anxiety measures,

for identifying individuals with repressive personality traits (e.g., Derakshan et al., 2007; Furnham et al., 2003; Weinberger et al., 1979).

Trait-Anxiety scale of the State-Trait Anxiety Inventory for Adults (Form Y-2) (STAI-T; Spielberger et al., 1983)

The STAI-T is a 20-item unidimensional self-report scale assessing anxiety-proneness. It asks respondents to evaluate the frequency of their feelings relating to each item-statement according to a four-point rating scale from "Almost Never" to "Almost Always". Higher overall scores indicate higher anxiety-proneness. During administration, which takes around six minutes, the STAI-S is referred to as the "Self-Evaluative Questionnaire" which is the title printed on the form itself (Spielberger et al., 1983). The STAI-T has been used for screening tertiary students and military recruits for anxiety problems and has proven to be a useful instrument for identifying people with high levels of neurotic anxiety and for selecting participants in psychological experiments (according to levels of motivation or drive) (Spielberger et al., 1983). The instrument possesses strong internal consistency, with coefficient alphas ranging between .91 and .92 for college students and working adults aged 19-39. The reliability of the STAI-T is also quite acceptable, with coefficient alphas of .73 and .77 at a 104-day test-retest interval, for male and female college students, respectively (Spielberger et al., 1983). Indeed, it remains the most used instrument for the assessment of trait-anxiety (Eysenck, 2000) despite contention over construct validity (e.g., Bieling et al., 1998; Ramanaiah, Franzen, & Schill, 1983).

Tests for Colour-Blindness (Ishihara, 1917, as cited in Birch, 1997)

An abbreviated version of Ishihara's *Tests for Colour-Blindness* (1917, as cited in Birch, 1997) was used to determine participants' ability to distinguish the colours green, yellow and red. This comprised six images consisting of a circle of dots appearing as random in colour and size. Imbedded within each image was an Arabic numeral clearly visible only to those enjoying normal red-green colour vision. Participants were also required to demonstrate accurate colour perception of all experimental stimuli during the practice session.

Design

The present experiment employed a 4 [Group: Low Trait-Anxiety, Medium Trait-Anxiety, High Trait-Anxiety, Repressor] x 2 (Trial: Control, Interference) mixed design. Following inspection of the ERP grand means, a further repeated measures factor was included for ERP analyses: Sagittal Site (Fz, Cz, Pz).

The behavioural dependent variables were response time (ms) and accuracy (percentages). The psychophysiological dependent variables were N1, P2, N2 and P3 amplitudes (μV) and latencies (ms). The ERP component parameters were defined after viewing the grand-average waveforms at locations of theoretical maxima (see Chapter 4); a process similar to that outlined in Wylie, Javitt, and Foxe (2003). The resultant ERP component amplitudes were ascertained as the maximum negative- or positive-going peaks, according to the polarity of the component, within the parameters reported in Table 7.4.

Table 7.5
ERP component parameters for peak detection (in milliseconds)

ERP Component	Stroop Stimuli	Control Stimuli
N1	60-120	60-120
P2	100-180	110-190
N2	160-320	150-330
P3	270-400	260-420

Data Analysis

Data from behavioural dependent measures were analysed by individual 4 [Group] x 2 (Trial) mixed ANOVAs. Data from each of the psychophysiological dependent measures underwent initial analyses according to the dictates of the hypotheses and topographical distributions for that component. Given there were no laterality effects expected, grand mean waveforms (presented as Figures 7.1, 7.2 and 7.3, below) were visually inspected for hemispheric asymmetry. As no such asymmetry was apparent,

only the midline sites were retained for statistical analyses. The hypotheses for P3 and N2 were constrained to Pz and Fz, respectively. Hence, these components each initially underwent 4x2 mixed ANOVA. The P2 and N1 components were maximal across multiple sites. Given this, analyses involving these included an extra factor, Sagittal Site. As such, P2 underwent initial 4x2x2 (Sagittal: Fz,Cz) mixed ANOVA, whereas N1 underwent initial 4x2x3 (Sagittal: Fz,Cz,Pz) mixed ANOVA. All of these initial analyses were identical for both amplitude and latency data. Huynh-Feldt corrections were applied, where appropriate, to control for any violations of sphericity. Tukey's HSD post-hoc tests were conducted to clarify the simple effects of significant interactions, and main effects, where necessary. All statistical tests were considered significant at alpha .05.

Results

Behavioural Data

Raw data were participants' individual response times on correctly performed trials. Response times (ms) were converted to means, and correct responses to percentages of the total number of valid trials. These data were then subjected to Repeated Measures ANOVAs, with Huynh-Feldt correction to degrees of freedom where appropriate. Tukey's HSD test was used to evaluate the significance of differences underlying main effects and interactions between factors, where necessary. Effects were considered statistically significant at, or below, p=.05. Only those results of theoretical significance are reported.

Response Latency

The Group x Trial mixed ANOVA revealed non-significant effects for both the main effect for Group, $F(3,64)=0.193$, MSE=18101, p=.901; and the Group x Trial interaction, $F(3,64)=0.550$, MSE=1962, p=.650. The main effect for Trial did reach significance, $F(3,64)=263.01$, MSE=1969, $p<.001$, $\eta^2=.800$, revealing that participants responded significantly faster to Control Trials (M=653.78, SEM=9.88), than Interference Trials (M=780.74, SEM=14.65) ($p<.001$). This indicates a strong Stroop interference effect.

Response Accuracy

As with Response Latency, the Group x Trial mixed ANOVA yielded non-significant findings for both the main effect for Group, $F(3,64)= 1.00$, MSE=1, p=. 0.678; and the Group x Trial interaction, $F(3,64)=1.00$, MSE=1, p=.483. The main effect for Trial did reach significance, $F(3,64)=8.00$, MSE=10, p=.005, $\eta^2=.110$; indicating that participants responded with greater accuracy to Control Trials (M=99.97, SEM=0.03), than Interference Trials (M=99.40, SEM=0.19) (p=.006). This is consistent with a Stroop interference effect.

ERP Data

Grand mean waveforms for both Interference and Control Trials, collapsed across groups, are presented in Figure 7.1. In addition to this, grand mean waveforms for each of the four groups are presented for Control Trials and Interference Trials in Figure 7.2. The grand mean waveforms presented in each of these three figures are scaled consistently. Whereas these show ERPs for midline sites only, full arrays are appended for inspection (see Appendices E, F and G).

Presented in Figure 7.1 are the grand mean waveforms for interference and control trials. Based on visual inspection, the N1 component shows no clear maxima, and little variation between Interference and Control trials, or across each of the three sagittal sites. The P2 component is maximal across Fz and Cz, where Control trials show larger and later P2 peaks than Interference trials. The N2 component is clearly maximal at Fz, and shows no difference across Trial type. The P3 component is clearly maximal at Pz, where it peaked slightly higher and earlier for Interference trials than for Control trials.

Presented in Figure 7.2 are the grand mean waveforms for control trials for each of the four groups. The N1 component shows slight variation between groups at Fz. This becomes much more apparent at Cz and Pz, where Repressors show greater amplitudes than all other groups, except the Medium Trait-Anxiety group at Pz. The P2 is largely consistent across groups at Fz and Cz, though less so at Pz where the Repressor group produced larger P2 amplitude than the other three groups. Anterior N2 is much larger, and slightly earlier, for the Repressor group than the Low Trait-Anxiety group; with these groups being intermediated by the Medium and High Trait-Anxiety groups. Finally, for P3, the Repressor group produced a much lower, and slightly earlier peak than each of the three other groups.

Also presented in Figure 7.2 are the grand mean waveforms for each of the four groups to Interference trials. For N1, both amplitude and latency are largely undifferentiated across both, Group and Sagittal location, at midline sites. The P2 component appears maximal across Cz and Fz, though peaked slightly earlier at the vertex. Group differences are not evident for either amplitude or latency for P2 at Pz; however, the Medium and High Trait-Anxiety groups show greater P2 amplitudes than the Low Trait-Anxiety and Repressor groups at Cz and Fz. Anterior N2 also shows

group differences, with amplitude being greater for Repressors and High Trait-Anxiety groups, than the Medium or Low Trait-Anxiety groups. Finally, the Pz site shows the Repressor group produced markedly lower P3 amplitude than all of the other three groups.

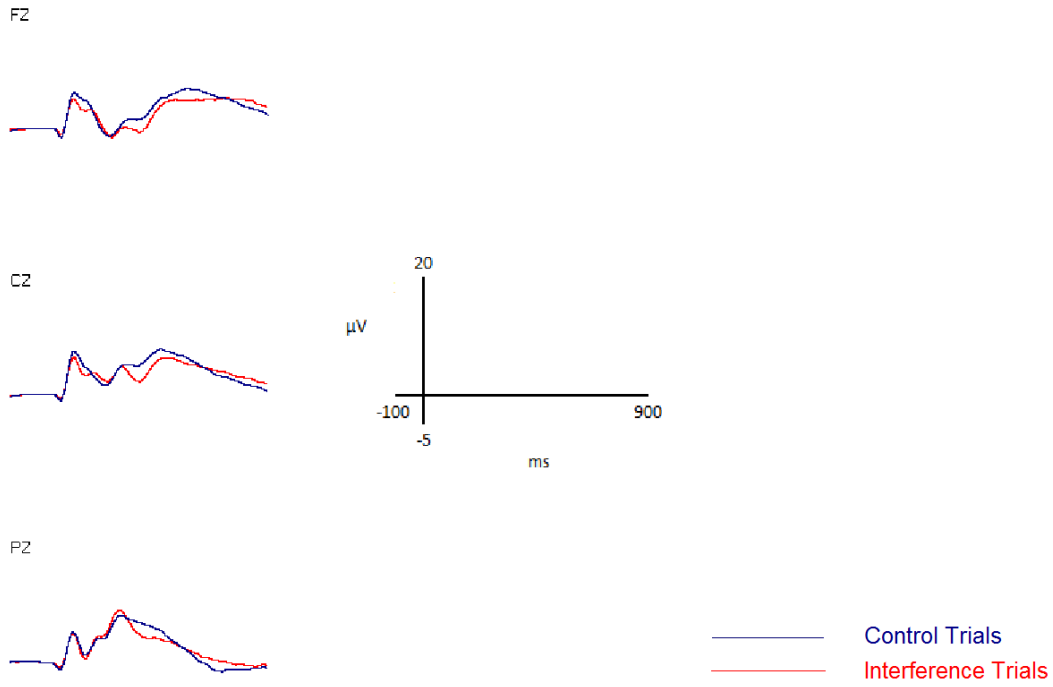

Figure 7.1. Grand mean waveforms for interference and control trials.

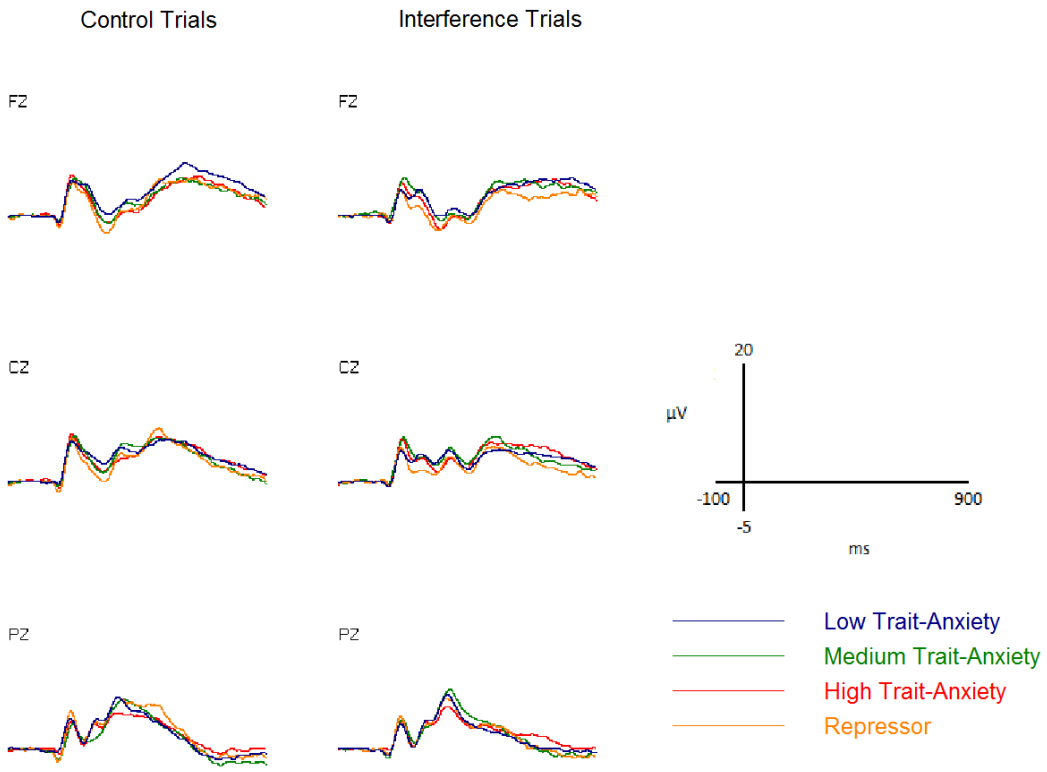

Figure 7.2. Grand mean waveforms for control trials and interference trials for each of the four groups.

Raw data were participants' EEG to trials that were responded to correctly. These were processed as described in the Method section. Each participant's peak amplitude (µV) and latency (ms) for the N1, P2, N2 and P3 components were initially subjected to 4 [Group] x 2 (Trial) mixed ANOVA at selected Sagittal sites, according to the dictates of the respective hypotheses and the topographical distributions of each component, as discussed earlier. Hence, N1 analyses included Fz, Cz and Pz; whereas P2 analyses included only Fz and Cz. Analyses for N2 were constrained to Fz, and those for P3 to Pz. Huynh-Feldt correction to degrees of freedom was applied where necessary. Tukey's HSD test was used to evaluate the significance of differences underlying main effects and interactions between factors where necessary. Effects were considered statistically significant at, or below, p=.05.

N1 Amplitude

The initial Group x Trial x Sagittal mixed ANOVA indicated the main effect for Group was not significant, $F(3,64)=1.18$, MSE=21.92, $p=.324$. Further, Group was shown not to interact significantly with Trial $F(3,64)=0.19$, MSE=7.14, $p=.159$. The main effect for Trial was also found not to be significant, $F(1,64)=0.10$, MSE=7.14, $p=.749$.

N1 Latency

The initial Group x Trial x Sagittal mixed ANOVA indicated the main effect for Group approached significance, $F(3,64)=2.51$, MSE=745.00, $p=.066$, $\eta^2=.105$, with the Latency of N1 increasing as a function of latent anxiety. Whereas the increment in Latency from the Low Trait-Anxiety Group ($M=84.75$, $SEM=2.32$) to the Medium Trait-Anxiety Group ($M=85.36$, $SEM=2.88$) was modest, the magnitude of this increased relative to the High Trait-Anxiety Group ($M=88.38$, $SEM=2.63$), and again to the Repressor Group ($M=95.04$, $SEM=3.22$). The Group x Trial interaction was not found to be significant, $F(3,64)=2.09$, MSE=374.00, $p=.111$; nor was the main effect for Trial $F(1,64)=0.96$, MSE=153, $p=.332$.

P2 Amplitude

The initial Group x Trial x Sagittal mixed ANOVA indicated non-significant findings for both, the main effect for Group, $F(3,64)=1.41$, MSE=58.36, $p=.248$, and the Group x Trial interaction, $F(3,64)=1.08$, MSE=7.35, $p=.366$. The main effect for Trial was found to be significant, $F(1,64)=11.02$, MSE=7.35, $p=.002$, $\eta^2=.141$. This showed mean P2 amplitudes to Control Trials ($M=11.47$, $SEM=0.53$) were larger than those to Interference Trials ($M=10.35$, $SEM=0.48$).

P2 Latency

As was the case with P2 amplitude, the initial Group x Trial x Sagittal mixed ANOVA for P2 Latency indicated non-significant findings for both the main effect for Group, $F(3,64)=0.58$, MSE=914.00, $p=.629$, and the Group x Trial interaction, $F(3,64)=0.68$, MSE=326.00, $p=.568$. The main effect for Trial, however, was shown to be significant, $F(1,64)=5.36$, MSE=326.00, $p=.024$, $\eta^2=.075$, revealing that P2 peaked earlier on Interference Trials (M=148.00, SEM=2.01) than Control Trials (M=153.21, SEM=2.37).

N2 Amplitude

The initial Group x Trial mixed ANOVA at Fz showed the main effect for Group to be significant, $F(3,64)=3.02$, MSE=37.04, $p=.036$, $\eta^2=.124$. The largest N2 amplitudes were produced by the Repressor Group (M=-5.91, SEM=1.24), followed by the High Trait-Anxiety Group (M=-4.03, SEM=1.01), and then the Medium Trait-Anxiety Group (M=-3.50, SEM=1.11), with the lowest amplitudes being produced by Low Trait-Anxiety Group (M=-1.48, SEM=0.90). Post-hoc testing, however, revealed the only significant difference to be that between the Repressor and Low Trait-Anxiety Groups ($p=.026$). Nevertheless, the pattern showed increased processing as a function of latent anxiety. Further, this result indicates a clear distinction in processing between the Low Trait-Anxiety and Repressor Groups. The Group x Trial interaction did not achieve significance, $F(3,64)=0.40$, MSE=7.81, $p=.755$; nor did the main effect for Trial $F(1,64)=0.28$, MSE=7.81, $p=.600$.

N2 Latency

The initial Group x Trial mixed ANOVA at Fz showed the main effect for Group as bordering on significance, $F(3,64)=2.73$, MSE=1673.00, $p=.052$, $\eta^2=.113$; however, this was subsumed by the significant Group x Trial interaction, $F(3,64)=3.67$, MSE=736.00, $p=.017$, $\eta^2=.146$. Figure 7.3 shows this interaction to be driven by the tendency for N2 produced by the Low Trait-Anxiety Group in response to Interference Trials to peak markedly earlier than: a) N2 produced by this Group in response to Control trials, and b) N2 produced by all other Groups in response to both Interference and Control Trials.

Post-hoc analysis revealed trends (*p*s ranging from .017 to .098) for all of these differences, with the exception of the High Trait-Anxiety Group on Control Trials (*p*=.377). The means and standard errors are presented along with the *p*-values from Tukey's post-hoc testing of comparison against N2 Latencies for Interference Trials from the Low Trait-Anxiety Group, in Table 7.4. This indicates that Low Trait-Anxious, when performing Interference Trials, executed preferentially rapid processing of the operations indexed by N2. The main effect for Trial was found not to be significant, $F(1,64)=0.29$, MSE=736, $p=.590$.

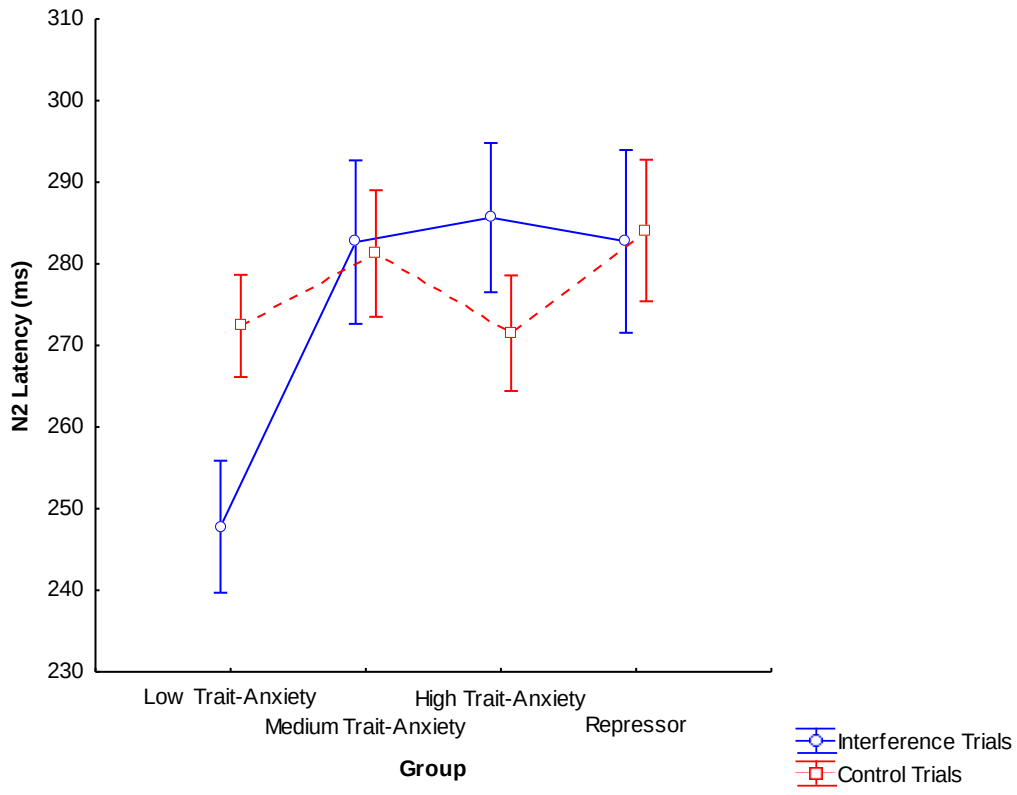

Figure 7.3. N2 Latency at Fz for Each of the Four Groups for Interference and Control Trials (vertical bars denote SEM).

Table 7.6
Means, Standard Errors (in parentheses), and p-values from Tukey's Post-Hoc Tests for the Group x Trial interaction at Fz for N2 Latency

Group	Trial	Mean	Standard Error	*p*-value
Low Trait-Anxiety	Interference	247.78	(8.09)	
	Control	272.39	(6.27)	.058
Med. Trait-Anxiety	Interference	282.67	(10.02)	.059
	Control	281.27	(7.76)	.081
High Trait-Anxiety	Interference	285.67	(9.15)	.017
	Control	271.50	(7.09)	.377
Repressor	Interference	282.75	(11.20)	.098
	Control	284.08	(8.67)	.075

Note. Significance = *p*-value from Tukey's post-hoc testing of comparison against N2 Latencies for Interference Trials from the Low Trait-Anxiety Group.

P3 Amplitude

The initial Group x Trial mixed ANOVA at Pz showed the main effect for Group not to be significant, $F(3,64)=1.55$, MSE=56.55, $p=.211$. Nor was the Group x Trial interaction found to be significant, $F(3,64)=0.58$, MSE=6.67, $p=.632$. The main effect for Trial did reach significance, $F(1,64)=4.30$, MSE=6.67, $p=.042$, $\eta^2=.061$, with P3 amplitudes to Interference Trials ($M=14.64$, $SEM=0.68$) shown to be larger than those to Control Trials ($M=13.69$, $SEM=0.72$). This indicates that Interference Trials required greater resource allocation indexed by P3 toward accomplishing the processing than did Control Trials.

P3 Latency

The initial Group x Trial mixed ANOVA at Pz revealed the main effect for Group not to be significant, $F(3,64)=0.27$, MSE=1500, $p=.848$. Nor was the Group x Trial interaction found to be significant, $F(3,64)=0.43$, MSE=1480, $p=.729$. As was the case for P3 amplitude, the only effect to reach significance for the analysis of P3 latency was the main effect for Trial, $F(1,64)=8.41$, MSE=1480, $p=.005$, $\eta^2=.114$, where P3 peaked

earlier to Interference Trials (*M*=321.16, *SEM*=2.77), than to Control Trials (*M*=340.84, *SEM*=6.22). Given the tendency for a negative relationship between the amplitude and latency of P3, this effect is as expected according to the finding of greater P3 amplitude to Interference Trials.

Discussion

The primary aim of the present experiment was to investigate prospective differences in the operation of attentional inhibition between individuals classified as either low trait-anxious, high trait-anxious, or repressors, in an emotionally neutral context. Participants responded verbally to trials presented in a single, mixed-block, with two conditions. The interference condition comprised classic Stroop incongruous colour-word trials, whereas the control condition comprised strings of the letter 'X' matched for colour, frequency and length.

In addition to measures of response time and accuracy, ERPs were employed to provide metrics of the timing and intensity of neural activity associated with cognitive resource allocation during task processing. An additional aim of the present experiment was to perform a general investigation of the ERP correlates of Stroop colour-word interference. While this secondary aim is worthy in its own right, it was undertaken opportunistically; in that it coincided with the primary aim of the experiment. This secondary aim is addressed at the beginning of the discussion of ERP effects, following discussion of the performance effects.

Performance Effects

The results of the present experiment provided support for both of the performance hypotheses. A very strong, highly significant effect was found whereby participants took longer to name the presentation colour of stimuli in interference trials than in control trials. Participants were also shown to make more errors when responding to interference trials than control trials. Together, these results provide unequivocal confirmation that classic Stroop interference was effected in the present experiment (MacLeod, 1991).

As anticipated, neither response speed nor accuracy was found to differ between the groups. This is not surprising given the neutral valence of the stimuli and relative crudity of these performance measures when compared to the intricacy of the early processing involved, along with the probable subtlety of strategic divergence between the groups. If, as proposed by Eysenck et al. (2007), trait-anxiety impairs processing efficiency more than it does performance effectiveness, then measures sensitive to the processing involved are required. Hence, ERPs were employed in the present experiment to provide indices of cognitive resource allocation during the rapidly occurring processing complex.

ERP Effects

The results of the ERP analyses provided less consistent findings, with regard to the hypotheses. Prior to more detailed discussion of these, however, a broader effect should be addressed. The prediction made with perhaps the greatest degree of certainty was the expectation of null findings relating to latencies across all components. As stated earlier, the most consistent ERP finding in Stroop research is the lack of effects involving latency. This was not found to be the case with the present experiment. Indeed, latency effects were found for each component: N1, P2, N2 and P3. These effects will be discussed in concert with amplitude effects, further on. Presently, however, the secondary aim of the current experiment will be discussed.

As has been noted, early ERP correlates of Stroop interference remain poorly understood. As such, a secondary aim of the present experiment was to perform a study of earlier-stage ERP correlates in Stroop colour-word interference; namely, N1, P2, N2 and P3. The results of the analyses performed on these showed relevant effects only for the P2 and P3 components.

Aside from the hypothesis of null findings relating to component latencies, the other hypothesis made with some degree of confidence was for P3 amplitude to be larger in response to interference trials than control trials. There was support for this hypothesis, though this was not strong. The marginally significant (p=.042) effect for larger P3 amplitude to interference trials was shown to account for little overall variance (η^2=.061). Although weak, this effect is consistent with previous findings of greater P3

amplitude in conditions of classic Stroop interference (Ilan & Polich, 2001) and threat-relevant interference in emotional Stroop paradigms (Thomas et al., 2007). The present result is somewhat bolstered by the finding of decreased P3 latency to interference trials. Although neither Ilan and Polich, nor Thomas et al. found concomitant latency effects, increases in P3 amplitude commonly result in shorter peak latencies.

As noted earlier, P2 was also found to differ as a function of classic Stroop interference. P2 amplitude was greater in response to control trials than to interference trials across Fz and Cz. Accounting for this effect may be assisted by the findings of Kieffaber and Hetrick (2005). As part of their investigation of ERP correlates of task-switching, these authors found attenuated P2 to switch trials, relative to repetition trials. Kieffaber and Hetrick interpreted this attenuated P2 as reflecting stimulus-dependent processes such as the retrieval of stimulus-response associations activated by salient properties of target stimuli. That is, attenuation of P2 as an index of lower stimulus-response association. This interpretation is consistent with the demonstrated Stroop interference in the present experiment. Consistent with P2 amplitude, P2 latency effects were observed across Fz and Cz.

Although there were no differences found between groups on response time, accuracy, P3 or P2, effects involving group were found for N2 and N1. In terms of theoretical significance, the clearest of these was the main effect for group differences in amplitudes for anterior N2. This comprised a clear pattern of N2 amplitude increasing as a function of latent anxiety. The largest N2 amplitudes were produced by the Repressor group (*M*=-5.91, *SEM*=1.24). The next highest, approximately 2μV lower, were produced by the High Trait-Anxiety group (*M*=-4.03, *SEM*=1.01), followed by a short drop to Medium Trait-Anxiety group (*M*=-3.50, *SEM*=1.11), with another 2μV drop to the Low Trait-Anxiety group (*M*=-1.48, *SEM*=0.90). Post-hoc testing showed only the difference between the Repressor and Low Trait-Anxiety groups to be significant. Nevertheless, this provides salient evidence of a manifest distinction between these groups on the processing indexed by anterior N2, which is believed to index conflict monitoring processes related to decisional or categorisation operations (Donkers & van Boxtel, 2004; Niewenhuis et al., 2003; Yeung et al., 2004). Further, despite the absence

of a full suite of significant post-hocs, the pattern for increased processing as a function of latent anxiety may be considered theoretically consistent and compelling.

The current finding of N2 amplitude increasing as a function of latent anxiety is the inverse of that initially predicted. The rationale underlying the hypothesis for the Repressor group to produce lower N2 amplitudes was based on the presumption that the critical inhibition involved in repression would take place earlier in the processing stream; at the stages of early selection, indexed by N1, and/or stimulus discrimination, indexed by P2. It was presumed that this early inhibition of task-irrelevant information would reduce the intensity of interference, and thus result in a reduction of resources required for conflict monitoring processes related to decisional or categorisation operations, thought to be indexed by anterior N2. The current results, however, suggest this is not the case. The increase in anterior N2 amplitude as a function of latent anxiety suggests that repressors remain open to interference. Further, it provides support for the proposals of Eysenck et al. (2007), that anxiety adversely affects processing efficiency more than performance effectiveness, and that anxiety reduces the ability of the attentional system to resist distraction.

The latency of anterior N2 also varied as a function of group. A trend toward a significant main effect for group was subsumed by a significant interaction with Trial type. Subsequent post-hoc tests revealed the N2 produced by the Low Trait-Anxious group to Interference trials as peaking earlier than, not only those they produced to control trials, but also those produced by all other groups, on both conditions (*p*s ranging from .017 to .098); the only exception being those produced by the High Trait-Anxiety group on Control trials (p=.377). Taken together with the findings for N2 amplitude, it appears that the Low Trait-Anxiety group, at least on Interference trials, execute the operations indexed by anterior N2 with greater efficiency than the other groups.

The current findings for N2 indicate an increase in processing with latent anxiety. This suggests that an earlier stage inhibition of task-irrelevant information does not take place, or is at least not sufficient to effect greater processing efficiency. Further, taken with the null findings for group differences on P3, there appears to be no evidence of a later stage advantage for Repressors and the Low Trait-Anxious. This has implications for the notion of the operation of a two-stage process in repression, as proposed in the

Vigilance-Avoidance Theory of Derakshan et al. (2007). The results of the analysis of N1 latency data, however, may mitigate the case for doubt over a two-stage process in repression.

The main effect for Group showed a trend (p=.066, η^2=.105), whereby N1 latency increased as a function of latent anxiety. Whereas the increment in latency from the Low Trait-Anxiety group (M=84.75, SEM=2.32) to the Medium Trait-Anxiety group (M=85.36, SEM=2.88) was modest, the magnitude of this increased relative to the High Trait-Anxiety group (M=88.38, SEM=2.63), and again to the Repressor group (M=95.04, SEM=3.22). This presents a pattern whereby the time taken to conduct the processes indexed by N1, namely early selection for further processing, increased as a function of latent anxiety. Further, this profile is consistent with that found for N2 amplitude, which also increased as a function of latent anxiety. Indeed, the concert of effects observed across the N1 and N2 components suggest a pattern of processing whereby engagement of cognitive resources associated with selective-attentional processing tends to increase with latent anxiety.

Summary and Conclusion

The present study employed a classic Stroop colour-word interference task to investigate the prospect of differential selective attentional processing between individuals classified as either low trait-anxious, medium trait-anxious, high trait-anxious, or repressors, in an emotionally neutral context. The primary aim was to investigate the inhibition of attention as a function of the disengagement sub-component of selective attention using ERP metrics. An additional aim of the present experiment was to perform a study of ERP correlates of Stroop colour-word interference, against a true control condition.

Analysis of the performance data confirmed the achievement of a strong classic Stroop interference effect. The P3 and P2 components showed clear sensitivity to this. The effect for increased P3 amplitude to Stroop interference is consistent with previous findings; both in conditions of classic Stroop interference (Ilan & Polich, 2001) and threat-relevant interference in emotional Stroop paradigms (Thomas et al., 2007). Further substantiating this effect was a concomitant decrease in P3 latency. Although

neither Ilan and Polich, nor Thomas et al. found these concomitant latency effects, increases in P3 amplitude commonly result in shorter peak latencies.

Conversely, P2 amplitude was greater in response to Control trials than Interference trials. This attenuated P2 was interpreted as reflecting increased stimulus-response ambiguity as a product of Stroop interference. In addition, this increase in processing activity was proposed to account for the observed increase in P2 latencies. Hence, the P3 and P2 components were found to be sensitive to Stroop interference in both amplitude and latency dimensions.

As was the case with Response Time and Response Accuracy, no evidence was found for the sensitivity of either P3 or P2 to differences in processing across any of the four experimental groups. Evidence of differential processing across groups was found, however, on both the N2 and N1 dependent measures. Anterior N2 amplitude was shown to increase as a function of latent anxiety, which provides support for the proposal of Eysenck et al. (2007), that anxiety has an adverse affect on processing efficiency.

This pattern of increased processing intensity as a function of latent anxiety at the stage of N2 was contrary to the expectation that the Repressor group would require fewer attentional resources for late-stage processing as a result of early-stage attentional gating of task-irrelevant information. It must be stated that the observed effect does not necessarily reflect a lack of effective inhibition of task-irrelevant information by the Repressor group, as groups were not found to differ on accuracy. Regardless, the present N2 effect, in concert with the absence of any group effects for P3, may support doubt over the operation of a two-stage vigilance-avoidance attentional mechanism in repression (as proposed by Derakshan et al., 2007).

This doubt was, however, mitigated by evidence of increased early-stage processing intensity as a function of latent anxiety found in the analysis of N1 latency. This profile is consistent with that found for N2 amplitude, which also increased as a function of latent anxiety. Taken together, the effects observed across N1 and N2 suggests a pattern of processing whereby engagement of cognitive resources associated with selective-attentional processing tends to increase with latent trait-anxiety.

To conclude, the results from the present Stroop colour-word experiment yielded no evidence of a later-stage processing advantage for the Repressor group. Evidence was found, however, indicating that demands on selective-attentional resources increase with an individual's level of latent trait-anxiety. Hence, the possibility of the operation of preattentional evaluation of stimuli for emotional significance in a two-stage process, such as that proposed by Compton (2003), remains open. Given the sensitivity of ERPs to both group and interference effects in the present experiment, it is suggested that any vigilance-avoidance operations are unlikely to have had a significant effect on processing within the classic Stroop colour-word paradigm. As such, in pursuit of the broader aims of the present thesis, what is required from here is further investigation of the degrees of operational flexibility possessed by these groups in the disengagement, shifting, and engagement subcomponents of selective attention (as detailed in Chapter 3).

Chapter 8: Task-Switching

Introduction

The broader scope of the current thesis concerns the prospect of differential selective attentional processing between individuals classified as either, Low Trait-Anxious, Medium Trait-Anxious, High Trait-Anxious, or Repressors in an emotionally neutral context. As discussed in Chapter 3, selective attention is considered to comprise three component processes: disengagement, shifting, and engagement. The experiment presented in the previous chapter was designed to investigate inhibition of attention as a strategic function of the disengagement sub-component of selective attention. The results of the previous experiment provided no evidence in support of the proposition that repressors possess superior ability to inhibit task-irrelevant information. There was, however, solid evidence found showing differential attentional processing between groups on several ERP components. Despite these differences being largely independent of Stroop-interference effects, these findings provide clear evidence of the sensitivity of ERPs to variations in cognitive resource allocation to attentional processing, as a function of latent anxiety.

Stroop paradigms can be integrated with task-switching paradigms. Such integration allows investigation of aspects of operational flexibility in the disengagement, shifting, and engagement subcomponents of selective attention. Indeed, to date two studies have shown task-switching to be affected by trait-anxiety (see Ansari, Derakshan & Richards, 2008; and Johnson, 2009). Whereas these effects occurred independently of ostensible emotion, there was no repressor group. Further, both of these studies used spatial orienting paradigms. Hence, the aim of the present study was to investigate the effect of latent trait-anxiety, including repression, on attentional resource allocation processes employed in task-switching within a non-spatial orienting paradigm.

The Task-Switching Paradigm

Adaptive negotiation of everyday life requires individuals to flexibly respond to changing environmental circumstances (Gajewski, Kleinsorge, & Falkenstein, 2010;

Kiesel et al., 2010; Monsell, 2003; Swainson, Jackson, & Jackson, 2006; Wylie, Javitt, & Foxe, 2003). Flexible shifting of attention between tasks involves complex cognitive control operations (Kiesel et al., 2010). These operations are predominantly concerned with the deactivation of task-irrelevant processing and activation of task-relevant processing (Gajewski et al., 2010).

Task-switching paradigms (e.g., Allport, Styles, & Hsieh, 1994; Jersild, 1927; Rogers & Monsell, 1995) have provided a useful means of investigating the mechanisms of attentional control involved in flexibly responding to the environment (Jost, Mayr, & Rösler, 2008; Karayanidis, Coltheart, Michie, & Murphy, 2003; Kiesel et al., 2010; Monsell, 2003; Nicholson, Karayanidis, Bumak, Poboka, & Michie, 2006). Despite greatly improved understanding over the past two decades of the processes involved in task-switching (see Kiesel et al., 2010; and Monsell, 2003 for excellent reviews), some fundamental questions are yet to be answered definitively. Because much of the current understanding concerning the processes involved in task-switching is not directly relevant to the present thesis, only those aspects directly pertinent will be discussed.

Task-switching experiments typically include two simple-choice reaction-time tasks. Participants perform trials on one task until required to switch to the other. Task stimuli are often bivalent, in that they hold two salient properties. Participants attend to, and process, different stimuli properties according to the requirements of the active task (Kiesel et al., 2010; Monsell, 2003). Switching instructions, and the number of trials between these, vary according to the particular methodology. Trials are categorised as *switch trials* or *repetition trials* according to consistency with the preceding trial.

Task processing efficiency can be improved by the configuration of procedural schema (Monsell, 2003). Such schema can include specific task-response rule mappings, referred to as *task-sets* (Monsell, 2003; Swainson et al., 2006). Well established task-sets tend to facilitate task performance when implemented intentionally, under appropriate circumstances; however, habitual activation of task-sets contrary to intention tends to impair performance. The Stroop effect is a classic example of this (Monsell, 2003). The robust effect for longer response times on switch trials compared to repetition trials is commonly referred to as a switching cost. These temporal switching costs are sometimes

accompanied by decremented accuracy (Jost et al., 2008; Kiesel et al., 2010; Monsell, 2003).

The observation that switching costs are generally reduced, though not eliminated, with advanced knowledge and/or increased preparation time has led to two primary theories regarding the sources of switching costs (Kiesel et al., 2010; Monsell, 2003; Pashler, Sohn, & Carlson, 2000; Pashler, 2001; Wylie et al., 2003). These are *task-set reconfiguration* (Rogers & Monsell, 1995) and *task-set inertia* (Allport et al., 1994). Task-set reconfiguration relates to endogenous interference resulting from reconfiguration of conceptual criteria according to conditional requirements. More specifically, task-set reconfiguration encompasses the processes involved in the inhibition of an active procedural schema, and the activation of a new one (Monsell, 2003). Task-set inertia, on the other hand, refers to exogenous interference caused by crosstalk arising from the enduring activation of the stimulus-response mapping of the previous task. Interference due to task-set inertia is particularly strong when task stimuli are bivalent, as they are relevant for each particular task, though in different ways (Allport et al., 1994; Gajewski et al., 2010; Kiesel et al., 2010; Rogers & Monsell, 1995).

Although the theories of *task-set reconfiguration* and *task-set inertia* were initially proposed as unitary competitors (Allport et al., 1994; Rogers & Monsell, 1995), the majority of evidence supports an integrative model of task-switching costs involving distinct, yet co-occurring, top-down and bottom-up processes (Kieffaber & Hetrick, 2005; Kiesel et al., 2010; Monsell, 2003; Pashler, 2001). While the co-occurrence of these processes poses challenges for the determination of the contribution of each to a switch cost, researchers have sought to strategically alter the qualitative demands of the processes of interest. This has seen the emergence of the *alternating-runs* and *task-cueing* paradigms.

In the alternating-runs paradigm (e.g., Rogers & Monsell, 1995), tasks alternate according to a predictable sequence. The advanced knowledge afforded through this predictability facilitates optimal efficiency in the initiation of the task-set reconfiguration process. This preparation effect is typically observed as reduced switch cost (Jost et al., 2008; Kiesel et al., 2010; Koch, 2003; Monsell, 2003).

In the task-cueing paradigm (e.g., Meiran, 1996; Sudevan & Taylor, 1987), cues are typically presented in advance of each trial to indicate which task is to be performed (Jost et al., 2008). The reduction in task predictability in this paradigm is considered to constrain preparatory processes when the cue-trial interval is sufficiently low. Whereas cue-trial intervals around 600ms have consistently been effective at constraining preparation, the effect is considered negligible when cue-trial intervals exceed 1000ms (Jost et al., 2008; Kiesel et al., 2010; Koch, 2003; Monsell, 2003). Hence, the task-cueing paradigm has the capacity to force greater overlap between the processes tackling task-set reconfiguration and task-set inertia than the alternating-runs paradigm.

The *intermittent-instruction* paradigm can be considered a sub-type of the task-cueing paradigm. It varies from the task-cueing paradigm in that task-cues are presented only prior to switches in task. That is, one task continues to be performed across a sequence of trials until the appearance of a cue instructing a task switch. The resultant increased novelty of cues is considered to be responsible for the more robust switch costs observed using this technique (e.g., Gopher, Armony, & Greenshpan, 2000)

The capacity to either increase or decrease overlap between task-set reconfiguration and task-set inertia processes, through task-cueing and alternating-runs paradigms provides opportunity to investigate differential effects associated with these processes. By distancing the onset of task-set reconfiguration and task-set inertia processes inferences can be made about changes in dependent measures observed in response to switch trials. These may be related directly to the respective contributions of top-down and bottom-up processing to the switch cost. An example of this is the preparation effect observed in the alternating-runs paradigm. Here, the earlier engagement of top-down processing toward the conduct of task-set reconfiguration effectively reduces the amount of activity required for processing the switch trial. Hence, at short inter-event intervals, switch trials in alternating-runs paradigms are less affected by top-down interference than those in task-cueing paradigms, which involve more co-occurring top-down and bottom-up interference.

The relative separability of top-down and bottom-up processing provides opportunity to investigate the operation of each of these in the context of attentional control. The combination of alternating-runs and task-cueing task-switching paradigms allows some

observation of the how top-down and bottom-up mechanisms contribute to the cost of switching tasks. Further, options such as increasing inter-event intervals, and employing intermittent task instructions, allow for increased scope for the investigation of individual differences in strength and flexibility of attentional control processes.

Task-Switching and Anxiety

The existing research on the effects of anxiety on attentional resource allocation processes associated with task-switching is limited (Derakshan, Smyth, & Eysenck, 2009). Ansari et al. (2008) investigated the effect of trait-anxiety on task-switching by comparing prosaccade and antisaccade performance across single-task and mixed-task blocks. Although the tasks were valence-neutral, only the low trait-anxious group were found to show the expected paradoxical switching benefit for antisaccade latency. Ansari et al. explained the lack of significant improvement by the high trait-anxiety group as the result of an inferior ability to utilise the task-cue to facilitate the process of task-set reconfiguration. They elaborated on this explanation from the perspective of Attentional Control Theory (Eysenck et al., 2007), suggesting individuals high in trait anxiety possess reduced ability to exercise top-down attentional control – and hence, are less able to efficiently shift attentional resources in accordance with demands of the new task.

Johnson (2009) used a task-cueing paradigm to investigate the relationship between trait-anxiety and switching between tasks requiring either emotion-judgement or shape-judgement. The stimuli were circles, squares, or triangles superimposed between the eyes of angry, happy, or neutral faces. His regression analysis revealed that switch costs were significantly moderated by trait-anxiety. This effect, where individuals higher in trait-anxiety exhibited greater switching deficiency, was independent of whether the judgement involved emotion. Johnson suggested that the undifferentiated switching deficiency in high trait-anxious individuals offers support for the Attentional Control Theory proposed by Eysenck et al. (2007).

Derakshan et al. (2009) employed both cued and un-cued mixed-task blocks, as well as single-task blocks, to investigate the effects of anxiety on attentional control. Participants were tasked with solving mathematical problems at two levels of

complexity. Both trait- and state-anxiety were measured at the beginning of experimental sessions, with state-anxiety also measured at the middle and end of sessions. Performance was affected only by state-anxiety at the beginning of the session, and only on the higher-complexity tasks. More specifically, participants classified as high in state-anxiety prior to testing showed increased switching-costs on the higher-complexity mathematical problems. Derakshan et al. drew on Attentional Control Theory (Eysenck et al., 2007) to interpret this finding.

According to Attentional Control Theory, optimal operation of the attentional control processes required to shift attention between and within tasks is impaired by anxiety. Derakshan et al. (2009) argue that such a deficiency in the high state-anxious group was betrayed under the increased greater demand on attentional control imposed by higher-complexity tasks. Hence, the subsequent increased difficulty in shifting attention led to greater switching costs. All other effects involving state-anxiety were relatively unremarkable, and there were no effects involving trait-anxiety.

The assertion by Derakshan et al. (2009), that their finding suggests state-anxiety impairs attentional control, is somewhat undermined by the lack of corroborating effect from the measure of state-anxiety taken midway through the blocks of experimental trials. An alternative explanation may be that the measure of state-anxiety taken at the beginning of the experimental session provided a better indication of anxiety-proneness than the measure of trait-anxiety. Regardless, it is clear that all three experiments reviewed in this section (i.e., Ansari et al., 2008; Derakshan et al., 2009; and Johnson, 2009) have found increased switching costs, on neutrally-valenced tasks, as a function of anxiety. Unfortunately, to date, no studies investigating anxiety and task-switching have included a repressor group.

Task-Switching and ERPs

Many studies have now used ERPs to investigate the attentional processes involved in task switching paradigms, and several ERP components have been associated with task switching processes (Kiesel et al., 2010; Sinai, Goffaux, & Phillips, 2007). Unfortunately, however, the wide variety of experimental and analytical methodologies employed has yielded a diverse range of findings. Hence, while components such as P1,

N1, P2, N2 and P3 have been investigated, there is no central agreement in the literature regarding ERP correlates in task-switching. This notwithstanding, effects involving the P3 component have shown some reliability (Sinai et al., 2007).

A number of studies have investigated ERP correlates of task cues using task-cueing paradigms whereby cues have preceded both switch and repetition trials. Many of these showed higher cue-locked P3 amplitude to cues that instructed participants to switch tasks than cues that instructed participants to continue the current task (e.g., Barceló, Periáñez, & Knight, 2002; Jost et al., 2008; Kieffaber & Hetrick, 2005; Kiesel et al., 2010; Rushworth, Passingham, & Nobre, 2002). As Karayanidis et al. (2003) explain, this P3 component likely comprises a number of overlapping potentials involved in reconfiguration of task-set and stimulus-response mapping. These authors suggest a task-set updating interpretation that is consistent with the context updating interpretation of P3 proposed by Donchin and Coles (1988). Barceló et al. agree with Karayanidis et al., as do Kieffaber and Hetrick, who explain that a central tenet of the context updating model is that P3 reflects processes involved in the planning and control of behaviour, such as setting perceptual biases and deploying attention. Indeed, there is an increasing consensus that enhanced P3 to cues instructing participants to switch tasks is likely to reflect preparatory processes related to task-set reconfiguration (e.g., Jost et al., 2008; Monsell & Mizon, 2006; Nicholson et al., 2006).

Moving on to P3 in response to switch trials, amplitudes have consistently been found to be smaller than those observed in response to repetition trials (e.g., Barceló, Escera, Corral, & Periáñez, 2006; Barceló et al., 2002; Gajewski & Falkenstein, 2011; Gajewski et al., 2010; Jost et al., 2008; Kieffaber & Hetrick, 2005; Kiesel et al., 2010; Kray, Eppinger, & Mecklinger, 2005; Lorist et al., 2000; Mayr & Kliegl, 2000; Monsell & Mizon, 2006; Rushworth et al., 2002, 2005; Sinai et al., 2010; Travers & West, 2008; West, 2004). Several ideas have been posited for the attenuated P3 in switch trials. Kieffaber and Hetrick, in discussing the topographical and temporal disparity between P3s they observed in response to cues and switch trials, suggest that this may reflect the operation of multiple generators, which may, in turn, be associated with unique anticipatory and stimulus dependent processes, respectively. Lorist et al. argue that switch trails are more processing intensive than repetition trials, resulting in fewer

resources being available for the accomplishment of other P3-related activities, and hence, reduced P3 (as per Kok, 2001; Wickens, Kramer, Vanasse, & Donchin, 1983). Verleger et al. (2005) have suggested that attenuated P3 in switch trials may be a product of increased response-related processing. They argue that any increase in the complexity of an operation – that is, switching versus repetition – will increase variability in performance. This greater variance results in increased latency jitter, producing lower, broader average waveforms. Gajewski and Falkenstein (2011) have dismissed this latency jitter explanation of Verleger et al. through demonstration of switch-related attenuation for both target- and response-locked P3. In addition to this, Gajewski and Falkenstein demonstrated an inverse relationship between N2 and P3 amplitude. By way of explanation, they proposed the operation of an anterior-posterior network that is differentially affected by carryover of task-set from the previous trial.

When compared to the extant research on P3 correlates in task-switching, studies reporting on the earlier ERP components thought to reflect more exogenous processing are far less abundant. Another factor hindering understanding of the functional correlates of these components in task-switching is that studies typically focus on switch costs, and often only report on difference waveforms (e.g., Karayanidis et al., 2003; Nicholson, Karayanidis, Poboka, Heathcote, & Michie, 2003). An exception is the recent work of Gajewski et al. (2010) that focussed on the role of the fronto-central N2 component in task-switching.

Gajewski et al. (2010) were interested specifically in the fronto-central N2 because it has been associated with conflict detection during response selection (e.g., Yeung & Cohen, 2006), and is particularly prominent in situations involving coactive incompatible response tendencies (see Folstein & Van Petten, 2008 for a review). In response to their task-cueing paradigm, Gajewski et al. found enhanced N2 on switch trials, compared to repetition trials. Whereas this experiment incorporated a go/no-go paradigm, which tends to evoke N2 (see Donkers & van Boxtel, 2004), the authors state that such N2 enhancement has been evident in several studies employing standard task-switching paradigms (e.g., Gehring, Bryck, Jonides, Albin, & Badre, 2003; Karayanidis et al., 2003; Kieffaber & Hetrick, 2005; Nicholson et al., 2003), though went largely unaddressed. Gajewski et al. concluded that fronto-central N2 reflects a decision process

involving the mapping of a stimulus onto a response category. Hence, the component is larger when interference between category-response associations requires resolution, such as on switch trials. Kieffaber and Hetrick displayed grand mean waveforms showing dissociable anterior N2 in response to switch and repetition trials (see their Figure 5.). Although Kieffaber and Hetrick did not report any analyses involving N2, the greater amplitude for switch trials was clearly apparent.

Kieffaber and Hetrick (2005) did, however, report on the earlier P2 component. This was significantly lower for switch, compared to repetition, trials. The authors proposed that P2 provided an index of the strength of stimulus-response association, in that it reflected stimulus-dependent processes such as the retrieval of stimulus-response associations activated by salient properties of target stimuli. Kieffaber and Hetrick also examined the N1 component, though found no effects of relevance to the present experiment. Taken together with theory relating to early attentional control process in anxiety, these reports provide some impetus for examining these earlier ERP components.

Rationale

The broader scope of the current thesis concerns the prospect of differential selective attentional processing between individuals classified as either, Low Trait-Anxious, High Trait-Anxious, or Repressors in an emotionally neutral context. As discussed in Chapter 3, selective attention is considered to comprise three component processes: disengagement, shifting, and engagement. Presented in Chapter 5 was a strong body of research evidence indicating that individuals high in trait-anxiety exhibit slower disengagement from threat than those low in trait-anxiety (Becker, Rinck, Margraf, & Roth, 2001; Mogg, Bradley, Williams, & Matthews, 1993; Mogg et al., 2000; Williams et al., 1996). Repressors, on the other hand, have been found to show facilitated disengagement of attention from threat (Fox, 1993; Mogg et al., 2000; Myers & McKenna, 1996; Newman & McKinney, 2002). Hence, whereas high trait-anxiety can be characterised by sustained vigilance, repression is thought to operate through a vigilance-avoidance process, where early threat detection facilitates rapid inhibition, and thereby protection from consciousness (Calvo & Eysenck, 2000; Derakshan et al., 2007).

As reviewed in Chapter 5, both Derryberry and Reed (2002), and Derakshan et al. (2009) found evidence supporting this assumption using emotion-neutral experimental tasks; a spatial orienting task, and an antisaccade task, respectively. Neither of these studies included a repressor group, however. Further, both experimental tasks involve a heavy qualitative emphasis on stimulus location, as opposed to stimulus features. Finally, the use of performance metrics in these studies lack the sensitivity to test a central proposition of the current thesis; that anxiety impairs attentional control regardless of the presence of threat-related or task-irrelevant stimuli (Eysenck et al., 2007).

The focus of the previous chapter (Chapter 7) was the presentation and discussion of an experiment designed to investigate inhibition of attention as a strategic function of the disengagement sub-component of selective attention. That experiment comprised a classic Stroop colour-word interference task. In addition to the classic performance indices of response time and accuracy, ERPs were employed to provide metrics of cognitive resource allocation, as behavioural measures are less sensitive to the subtle processing involved in these operations. The ERP analyses indicated differences in attentional resource allocation as a function or latent anxiety. These group effects, however, were not found to interact meaningfully with Stroop interference. Hence, the attentional resource allocation associated with Stroop inhibition does not appear to be modulated by latent anxiety. Given this, and the broader aims of the present thesis, it was suggested that what was required was investigation of the degrees of operational flexibility possessed by these groups in the disengagement, shifting, and engagement subcomponents of selective attention (as detailed in Chapter 3).

As discussed earlier, task-switching paradigms allow the investigation of operational flexibility in the disengagement, shifting, and engagement subcomponents of selective attention. This is particularly the case when bivalent stimuli are employed. Indeed, two recent studies have shown performance measures on task-switching to be affected by trait-anxiety (see Ansari et al., 2008; and Johnson, 2009). Importantly, these effects occurred independently of ostensible emotion. Unfortunately, to date, no studies investigating the relationship between anxiety and task-switching have included a

repressor group. Addressing this shortcoming would provide opportunity for the investigation of a vigilance-avoidance operation in repression (presented in Chapter 5).

The aim of the present study was to investigate the effect of latent trait-anxiety on attentional resource allocation processes employed in task-switching. Participants classified as either: low, medium, or high trait-anxious; or repressors, performed neutrally-valenced switching tasks comprising bivalent stimuli. The influence of bottom-up and top-down factors were investigated through analysis of ERP and performance data from two task-switching paradigms; those being task-cueing and alternating-runs.

As discussed earlier, relatively rapid inter-event intervals (i.e., 200ms – 600ms) are typically employed when comparing cognitive processing between task-cueing and alternating-runs paradigms. This allows maximum control over the overlap of task-set reconfiguration and task-set inertia processes, which in turn allows clear observation of a preparation effect. Such close spacing of events, however, is not desirable within ERP methodology due to the susceptibility of ERPs to proactive and/or retroactive influence. An excellent example of this appears in the grand mean waveforms presented by Jost et al., when comparing cue-stimulus intervals of 200ms and 1000ms (see their Figure 2). This presents a dilemma when considering the spacing of events, as the preparation advantage is considered lost when cue-stimulus intervals broach 1000ms.

Nevertheless, it is possible to investigate endogenous and exogenous influences in task-switching while employing stimulus onset asynchronies more conducive to ERP measurement. This may be achieved by exercising the intermittent-instruction option within the task-cueing paradigm, whereby task-cues are presented only when instructing a task-switch. Here, if cues are comprised of attributes that are distinct from those of task stimuli, then they would likely disturb persistence of the task-set configuration; with the resultant interference likely to temper task-set inertia.

Whereas this approach provides opportunity for investigation of processing associated with task-set inertia, it does so at the expense of task-set reconfiguration processing. Task cues, however, provide an opportunity to redress this. As discussed earlier, there is increasing consensus that enhanced P3 to switch-cues relative to repeat-cues is associated with the onset of task-set reconfiguration processes. Given this, ERP correlates of task-cueing provide an avenue for the investigation of preparatory

processing in task-switching; processing which, in relative terms, may be considered wholly endogenous.

Prior to presenting hypotheses for the present experiment, it is important to note that in order to provide the simplest of response choices, bivalent task stimuli were configured in arrays that could be considered *local-global* in nature (cf. Navon, 1977). This is due to the use of number-numerosity tasks (detailed in the Method section) which required response to either: a single digit within a group of digits (number/local), or the number of digits that comprise the group (numerosity/global). As such, reference to local-global effects will be made. Discussion of these will, however, be constrained to the focus of the current study.

Further, as discussed earlier, the literature on the ERP correlates of task-switching lacks cohesion due to the wide variety of experimental and analytical methodologies employed. Given this, the ERP correlates of task-switching within the present study would be worthy of comprehensive investigation, and discussion with reference to the broader literature in the area. In the interests of focus and brevity, however, reporting of ERP results were constrained to group effects. Whereas all main effects for group were reported, interactions involving group were only reported when these achieved or approached statistical significance. Three exceptions to this are made. These involve main effects that were hypothesised for the purpose of validation in the form of replication of effects from previous research.

Hypotheses

The current dearth of research on the effects of anxiety on attentional resource allocation processes involved in task-switching makes formulation of precise predictions difficult. This is particularly so in the case of ERPs. Nevertheless, specificity in some aspects is possible to some degree.

The experimental stimuli employed in the present task-switching paradigms could be considered local-global in nature. Inspection of the Method section of the current chapter, however, reveals that the local-global properties of the experimental stimuli employed presently differ markedly to those used in experimental research on the classic local-global effect (cf. Navon, 1977). Hence, the present experimental tasks were not

expected to elicit strong local-global effects. Nevertheless, should local-global effects be found these were expected to be consistent with the global precedence effect, whereby processing of local stimuli is impaired by the precedence of global features in the processing stream. Specifically, any global precedence effect would affect local processing as follows: for performance measures, lower accuracy and greater response latency; and for ERP measures, lower amplitudes and greater peak latencies for each, or any, of the N1, P2, N2 and P3 components (e.g., Beaucousin et al., 2011; Machinskaya, Krupskaya, & Kurgansky, 2010; Proverbio, Minniti, & Zani, 1998). Further, should such ERP effects occur, these were considered most likely to interact with latent anxiety in accordance with the hypothesised effects for each component, as articulated below.

Performance Measures

Response Latency

In accordance with the large and consistent body of research findings for switch-costs (see Gajewski & Falkenstein, 2011), response latencies were predicted to be significantly longer to switch trials than repetition trials. Given the stimuli used in the present study were ostensibly non-valent, response latency was not predicted to be sensitive to differential processing among groups. Nevertheless, due to the propensity for high trait-anxious individuals to show retarded disengagement (see Chapter 5) this group was thought to be more likely than the three remaining groups to produce longer response latencies; particularly on switch trials.

There was also the potential for differences in response times between trials on the alternating-runs and task-cueing paradigms. The combination of extra processing time and interference of task-set inertia afforded by the task-switching cue was considered more likely to result in shorter response latencies to switch trials in the task-cueing paradigm, compared with the advantage of predictability afforded in the alternating-runs paradigm.

As was the case with effects of trial type, there was no strong expectation that differential processing between groups across the paradigms would be observable in response latency. This not withstanding, however, it was considered that should the reduced preparation time afforded in the alternating-runs paradigm affect group

differences, this would most likely be in the form of protracted responses by the high trait-anxiety group; again, as a function of the propensity for high trait-anxious individuals to show delayed disengagement of attention.

Response Accuracy

As discussed previously in the present chapter, switch-costs can also include decrements in response accuracy (Gajewski & Falkenstein, 2011). The effect of increased error rate on switch trials, compared to repeat trials, is not as robust as that of increased response latency, however. Nevertheless, it was expected that any differences in response accuracy would manifest according to the profiles outlined for response latency, above.

ERP Measures

As mentioned earlier, despite a number of studies having used ERP measures to investigate the attentional processing in task-switching, the somewhat desultory nature of the experimental and analytical methodologies has resulted in a diverse range of findings. With the exception of attenuated P3 (see Sinai et al., 2007), no other ERP correlates have been established for switch trials. ERP-related hypotheses proposed in the present experiment are presented with according confidence. Regarding the latency dimension of ERP correlates of task-switching, the body of existing research relevant to the current study is scant. Hence, unless otherwise stated, latency effects were not expected.

P3

In accordance with consistent findings to date, P3 amplitude was expected to be lower in response to switch trials than repetition trials. The strongest explanation for attenuated P3 to switch trials is that of reduced resource availability as a consequence of increased processing demands (as per Kok, 2001; Wickens et al., 1983). Given the association between high trait-anxiety and retarded attentional disengagement, it was expected that any group differences in P3 amplitude would be in the direction of lower P3 amplitude for the high trait-anxiety group compared to each of the other three groups;

particularly on switch trials. According to the vigilance-avoidance model, repressors were expected to show similar P3 activity to the low and medium trait-anxiety groups at this relatively late stage in attentional processing.

In response to switch-cues, P3 was expected to provide an index of the relative allocation of cognitive resources to preparatory processing undertaken by each of the groups. In lieu of research that would guide the formulation of sound hypotheses, the following suggestions are offered. First, the medium trait-anxiety group is most likely to represent processing that can be considered as moderate, and so serve as a control against which to reference the processing of the other three groups. Second, the notion of enhanced P3 to switch-cues as indexing increased preparatory processing related to task-set reconfiguration may not adequately reflect the divergence in processing by the groups of interest to the current thesis. Indeed, it may be too simplistic. Take the case of lower relative P3 amplitude, for instance. For the low trait-anxiety group, this may reflect reduced processing associated with a conservative strategy; whereas for the high trait-anxiety and/or repressor group/s, this might reflect reduced resource availability due to competing demands. As such, predictions are reserved in deference to discussion of results. Regardless of the above, given P3 has been well established as a parietal component, P3 analyses will be constrained to the Parietal site.

N2

Similarly, analyses on N2 will be constrained to the Fz, as it is the anterior subcomponent of N2 that is of interest to the present work. Anterior N2 has been associated with conflict detection during response selection (see Yeung & Cohen, 2006), and is particularly prominent in situations involving coactive incompatible response tendencies (see Folstein & Van Petten, 2008 for a review). Given the emerging evidence for enhanced N2 to switch trials (e.g., Gajewski & Falkenstein, 2011; Gajewski et al., 2010), it was expected that N2 amplitude would be greater in response to switch trials than repetition trials.

In considering prospective group differences on switch trials from the vigilance-avoidance perspective, an initial assumption may be that N2 effects would concur with those proposed for P3 amplitude. That is, the high trait-anxiety group will produce larger

N2 amplitudes than the other three groups due to retarded attentional disengagement. The findings from the Stroop experiment presented in the previous chapter, however, challenge this assumption. The results from the Stroop experiment showed that, contrary to the expectation that repressors, owing to advanced ability for critical inhibition early in the processing stream, would show reduced N2 amplitudes to interference stimuli, the repressor group actually produced the largest N2 amplitudes. This finding suggests that repressors may indeed be more susceptible to interference from task-irrelevant information than each of the other groups. Hence, it would not be unexpected to find larger N2 amplitudes produced by repressors, than each of the other groups; perhaps even in the pattern observed in the Stroop experiment, whereby N2 amplitude to interference stimuli was shown to increase as a function of latent anxiety. If this were to be the case, such a finding would add collateral evidence to the prospect that repressors remain open to interference from unwanted information at the stage of conflict detection during response selection.

Regarding switch-cues, the proposal of hypotheses is frustrated by the dearth of research on N2 correlates in task-cueing. As such, suggestions about effects are offered advisedly. Accordingly, should cue processing involve processing associated with N2, then effects would likely shape as per the profile proposed for switch trials. That is, for N2 amplitude to increase as a function of latent anxiety.

P2

Within the literature relevant to the present study, it would appear that the only work to report on P2 and N1 correlates of task-switching is that of Kieffaber and Hetrick (2005). These authors found attenuated P2 to switch trials, which they interpreted as reflecting stimulus-dependent processes such as the retrieval of stimulus-response associations activated by salient properties of target stimuli. That is, attenuation of P2 as a function of lower stimulus-response association. On the basis of this finding, P2 amplitude in the present study was expected to be lower in response to switch trials than repetition trials.

Given the prospect that repressors may possess superior attentional flexibility, it was considered that this may facilitate stimulus-response association. As such, it was

tentatively proposed that repressors would show larger P2 amplitude to both switch and repeat trials, compared with each of the other three groups. Further, given the negative relationship between trait-anxiety and attentional disengagement, it was considered that the high trait-anxiety group would be more vulnerable to proactive interference from the previous response-set. Hence, it was expected that the high trait-anxiety group would show lower P2 amplitude to switch trials than each of the other three groups.

For the processing of switch-cues, expectations and reasoning were identical to those stipulated for P2 to switch trials. Notwithstanding this, due to the qualitative differences in these events, the likelihood of observing such effects was considered to be lower in the case of P2 to switch-cues.

N1

As noted directly above, Kieffaber and Hetrick (2005) also investigated N1 correlates in task-switching. There were, however, no effects for N1 that were of relevance to the present thesis. Nevertheless, as N1 is considered to provide an index of attentional processes involved in early selection for further processing, some tentative hypotheses may be proposed. Should repressors and high trait-anxious participants engage in enhanced early processing toward rapid threat detection, then this would be evidenced by enhanced N1 amplitude, and/or latency in these groups. These effects would likely be stronger for switch trials than repeat trials, though not necessarily stronger for switch-cues.

Method

Participants

As detailed in the Procedure sub-section, below, each person who participated in the current study also participated in the experiment presented in Chapter 7, and vice versa. Hence, all information regarding the selection of participants is identical to that presented in the Method section of Chapter 7. Unfortunately, however, data from 12 participants in the current study were discarded, resulting in a different profile of

experimental participants. Prior to describing the characteristics of those whose data were retained for analysis in the present study, explanation of the exclusions should be provided.

As detailed in the *Task and Stimuli* sub-section, below, an adjustment was made to the Alternating-Runs paradigm following participant feedback. This resulted in all data collected to that point being discarded. This comprised seven participants, all from the Low Trait-Anxiety group. In addition, four participants from the High Trait-Anxiety group and one participant from the Repressor group had their data discarded due to inability to maintain response configuration throughout at least one experimental block.

Hence, the experimental sample comprised 57 right-handed female psychology students from the University of Tasmania aged between 18 years, 2 months, and 33 years, 3 months (M = 20 years, 7 months, SD = 3 years, 4 months). Of these, 44 were first-year students who participated in exchange for partial course credit, eight were first-year students who were paid $30 for their time, with the remaining five being psychology post-graduate students volunteering their time. The characteristics of the experimental sample are presented in Table 8.1, along with comparison to those of the initial screening respondents, the subsequent prospective participant pool, and normative samples from the STAI Manual (Spielberger, 1983).

Table 8.1
Comparison of initial respondents, experimental pool, experimental participants, and normative samples on sample size and STAI-T score characteristics

Sample	N	STAI-T			
		Mean	SD	Minimum Score	Maximum Score
Initial Screening Respondents	446	41.84	9.49	21	70
Participant Pool	391	41.63	9.62	21	70
Experiment Participants	57	39.49	11.17	23	70
Female University Students (STAI Manual)	481	40.40	10.15	n/a	n/a
Working Females Aged 19-39 (STAI Manual)	210	36.15	9.53	n/a	n/a

Note. The STAI (Form Y) Manual (Spielberger, 1983) provides normative data only for select samples, with data for males and females presented separately.

One-way ANOVAs conducted on mean age and STAI-T scores found that the experimental groups were not significantly different on mean age $F(3,53)=0.42$, MSE=1687, $p=.743$, however a significant main effect was found for total STAI-T score, $F(3,53)=128.12$, MSE=15.98, $p<.001$, $\eta^2=.879$. Tukey HSD post-hoc tests revealed that the mean STAI-T score for the High-Anxious group was significantly higher than that of the Medium-Anxious group, which was significantly higher than the mean total STAI-T score for the Low-Anxious and Repressor groups ($ps<.05$). The Low-Anxious and Repressor groups did not differ ($ps>.05$). These means and standard deviations are presented in Table 8.2.

Table 8.2
Comparison of the Low, Medium and High Anxious groups, and the Repressor group from the participant pool and the experimental groups on sample size and STAI-T score characteristics

Sample	N	STAI-T			
		Mean	SD	Minimum Score	Maximum Score
High Pool	93	54.40	5.03	49	70
High Experimental	14	55.50	6.62	49	70
Medium-High Pool	66	46.03	1.43	44	48
Medium Pool	63	41.51	1.11	40	43
Med. Experimental	16	41.63	1.20	40	43
Low-Medium Pool	76	37.40	1.34	35	39
Low Pool	93	29.27	3.91	21	34
Low Experimental	16	30.44	2.03	25	33
Repressor Group	11	29.18	4.40	23	34

Materials, Apparatus & EEG Recording

All materials, apparatus and EEG recording were as described in Chapter 7.

Tasks and Stimuli

Two task-switching paradigms were used in the present experiment: an alternating-runs paradigm, and a task-cueing paradigm. Both paradigms employed bivalent number-numerosity stimulus sets, which were configured similarly to those used in previous experiments (e.g., Allport et al., 1994; Koch, 2003; Logan & Bundesen, 2004). The imperative task stimuli were digits. These were presented as either a single digit or in groups ranging in size from two and nine. The digits used were: 1, 2, 3, 4, 6, 7, 8, and 9. Each digit was presented 11 times in group sizes corresponding to the amount denoted by each of the other six digits, but never corresponding to that denoted by the digit. For instance, the numeral ‘9’ was presented 11 times as a single digit, and in groups of two, three, four, six, and eight, but never in a group of nine.

Each digit was displayed as white on a black background in 72 point Times New Roman font. Groupings were presented in the same spatial configuration used for suit markers on playing cards and were presented within an 8cm x 12cm area enclosed within a 2mm white border that appeared simultaneously with the stimuli. The bivalent nature of the target stimuli presumed a Stroop interference-like nature to the tasks (Stroop, 1935), while the grouping of digits in the present context presumed a local-global nature to the tasks (e.g., Navon, 1977). All target stimuli were presented for 500ms with an ISI of 1500ms. This 2000ms SOA incorporated a 1900ms response window which began 100ms post stimulus onset. These SOA are similar to those employed by Kieffaber and Hetrick (2005) in their study of ERP correlates of tasks-switching.

Participants were required to respond according to whether the relevant attribute of target stimuli represented an amount that was less or greater than five. The local task required participants to respond according to the amount denoted by the digit. The global task required participants to respond according to number of digits that comprised the stimuli.

Alternating-Runs Paradigm

In the Alternating-Runs paradigm, participants were instructed to alternate between the local and global tasks after every third trial (i.e. AAA BBB AAA, cf., Wylie et al., 2003). Despite successful piloting, several experimental participants reported loss of confidence in the accuracy of their sequencing. To address this, all data were discarded and the software rewritten to include task indicators to assist participants in maintaining sequence. These reminders took the form of the words ‘Digit’ and ‘Group’ displayed in 72 point Arial font at the bottom-left, and bottom-right, edges of the monitor, respectively. Reminders appeared 500ms after the offset of the final target of the previous run (1000ms prior to the first target of the new run) and remained visible until the offset of the final target of that run.

A study conducted by Koch (2003) provides information relevant to consideration of the prospective qualitative effects of these inclusions. Koch investigated the effects of internal versus external sequence tracking, along with preparation interval, within an

alternating-runs paradigm. He found that, relative to internal sequence-tracking, the preparation effect was stronger with external assistance when the inter-trial interval was increased from 200ms to 1000ms. Hence, given the increased length of inter-trial interval in the present experiment, these reminders were expected to assist in the preservation of the preparation effect through mitigation of any interference and/or attrition.

Task-Cueing Paradigm

Task-switches were less predictable in the Task-Cueing paradigm than the Alternating-Runs paradigm. In the Task-Cueing paradigm, participants were required to perform either, the local or the global task, according to a switching cue pseudo-randomly presented after every third, fourth or fifth trial (e.g., AAAA * BBB * AAA * BBBBB). Task-switching cues comprised the instructive phrases 'Name Digits' and 'Count Digits' presented as white in 72 point Arial font and appeared simultaneously within the centre of the same border presented around target stimuli.

Task-switching cues were presented 1500ms after the offset of the preceding target stimulus and appeared for 500ms, prompted participants to switch to the ensuing task. The task-switching cues were followed by a black screen for 1500ms, until the presentation of the switch-trial. In order to maximise stimulus-context consistency with the Alternating-Runs paradigm, the peripheral task-reminders employed in that paradigm were included in the present paradigm; however, these remained present until the presentation of the task-switching cue, alternating at that moment.

Procedure

The initial procedure up until the introduction of the experimental task was identical to that described in Chapter 7. A review of the Method section presented in Chapter 7 will show that this involved participants reading an information sheet (see Appendix C) and signing a statement of informed consent (see Appendix D) – in accordance with the approval (H8493) granted by the *Human Research Ethics (Tasmania) Network.*

Participants were seated in a sound attenuated room at a distance of approximately 70cm from the computer monitor and given a general overview and demonstration of the

task and response requirements. This was followed by a more specific instruction and practice session pertaining to the ensuing condition. Participants responded by button-press on a standard keyboard, either with the left index finger on the ‘Z’ key, or the right index finger on the ‘?’ key. Response requirements were identical across tasks, in that the same button was pressed for a response of less-than-five regardless of whether the task was local or global.

Two response configurations were employed in the present experiment. One configuration required participants to use the left index finger to respond as less-than-five (Left/Less), and the right index finger to respond as greater-than-five (Right/Greater). The other configuration was vice versa (Left/Greater and Right/Less). These two response configurations were incorporated as a means of mitigating any response-hand laterality effects associated with either task-reminder congruence (Simon, 1969) or inter-hemispheric transmission times for local and global stimuli (Fink et al., 1997). As such, participants completed each paradigm twice, once with each response configuration. This equated to four experimental conditions.

Counterbalancing for order was conducted at two levels: first, at the level of paradigm; second, at the level of response configuration. Alternating-Runs conditions ran for 6.5 minutes and Task-Cueing conditions for 7.0 minutes. Participants were offered rest at the completion of each condition, following which they were instructed and offered practice on the next condition. With instructions, practice sessions and breaks the current experiment took approximately 50 minutes to complete. In addition, as detailed in the Method section presented in Chapter 7, between the first and second task-switching paradigms participants spent around 10 minutes completing a Stroop task. No participants reported, or appeared to experience, adverse reactions to the experimental procedure. An anonymous examiner of the present dissertation requested inclusion of data on the number of trials included in the ERP waveforms for each experimental group, in each condition. These are presented for the Alternating-Runs Paradigm in Table 8.3 and the Task_Cueing Paradigm in Table 8.4. Data for waveforms for Cues presented in the Task_Cueing Paradigm are presented in Table 8.5.

Table 8.3
Comparison Across Groups on Numbers of Trials Included in ERP Waveforms for Each Task and Trial Type (Numbers of Excluded Trials Appear in Parentheses), for the Alternating-Runs Paradigm.

		Local		Global	
Group	N	Switch	Repeat	Switch	Repeat
Repressor	11	612 (92)	1281 (127)	598 (106)	1253 (155)
High Trait-Anxiety	14	761 (135)	1594 (198)	779 (117)	1630 (162)
Med. Trait-Anxiety	16	885 (139)	1853 (195)	900 (124)	1889 (159)
Low Trait-Anxiety	16	875 (149)	1832 (216)	909 (115)	1879 (169)

Table 8.4
Comparison Across Groups on Numbers of Trials Included in ERP Waveforms for Each Task and Trial Type (Numbers of Excluded Trials Appear in Parentheses), for the Task-Cueing Paradigm.

		Local		Global	
Group	N	Switch	Repeat	Switch	Repeat
Repressor	11	535 (81)	2242 (222)	542 (74)	2316 (148)
High Trait-Anxiety	14	678 (106)	2838 (298)	682 (102)	2853 (283)
Med. Trait-Anxiety	16	797 (99)	3333 (251)	801 (95)	3351 (233)
Low Trait-Anxiety	16	788 (108)	3297 (287)	788 (108)	3297 (287)

Table 8.5
Comparison Across Groups on Numbers of Trials Included in ERP Waveforms for Each Task-Cue Type (Numbers of Excluded Trials Appear in Parentheses), for the Task-Cueing Paradigm.

Group	N	Local	Global
Repressor	11	598 (18)	601 (15)
High Trait-Anxiety	14	769 (15)	771 (13)
Med. Trait-Anxiety	16	880 (16)	884 (12)
Low Trait-Anxiety	16	875 (21)	881 (15)

Design

The present experiment was designed to investigate both preparatory and contemporaneous cognitive processing associated with task-switching. This required the observation of three event types: switching cues, switch trials and repeat trials. It was therefore practical to segment the present experimental design. The processing of switch cues comprised the preparation segment, with switch and repeat trials comprising the task execution segment.

Beginning with the task execution segment, a 4 [Group: Low-Anxious, Medium-Anxious, High-Anxious, Repressor] x 2 (Paradigm: Alternating-Runs, Task-Cueing) x 2 (Task: Local, Global) x 2 (Trial: Switch, Repeat) mixed design was used. Following inspection of the ERP grand means, a further repeated measures factor was included for ERP analyses: Sagittal Site (Fz, Cz, Pz). The behavioural dependent variables were response time (ms) and accuracy (percent correct). The psychophysiological dependent variables were N1, P2, N2, and P3 amplitudes (μV) and latencies (ms). These ERP component parameters were defined after viewing the grand-average waveforms at locations of theoretical maxima (see Chapter 4); a process similar to that outlined in

Wylie et al. (2003). The resultant ERP component amplitudes were ascertained as the maximum negative- or positive-going peaks, according to the polarity of the component, within the parameters reported in Table 8.6.

The switch-cueing segment comprised a 4 [Group: Low-Anxious, Medium-Anxious, High-Anxious, Repressor] x 2 (Task: Local, Global) mixed design. Following inspection of the ERP grand means, the repeated measures factor for Sagittal Site was again included for ERP analyses. The psychophysiological dependent variables were N1, P2, N2, P3 amplitudes (μV) and latencies (ms). These component parameters were defined exactly as per the task execution stage, described directly above (see again, Table 8.6). As participants were instructed not to register responses to task-cues, there were no behavioural dependent measures for the task-cueing segment of the present experiment.

Table 8.6

ERP component parameters for peak detection (in milliseconds)

ERP Component	Alternating-Runs	Task-Cueing
N1	75-140	75-140
P2	100-250	100-250
N2	180-350	180-350
P3	255-600	255-600

Data Analysis

Task-Execution

Data from behavioural dependent measures associated with task-execution were analysed by individual 4 [Group] x 2 (Paradigm) x 2 (Task) x 2 (Trial) mixed ANOVAs. Data from each of the psychophysiological dependent measures underwent initial analyses according to the dictates of the hypotheses for that component. The hypotheses for P3 and N2 were constrained to Pz and Fz, respectively. Hence, data from these

components were subjected to 4x2x2x2 mixed ANOVAs at the respective sagittal sites. As discussed earlier in the present chapter, current understanding of the functional correlates of N1 and P2, including relationships between function and topography, is not nearly as well advanced as that for N2 and P3. In the visual modality, N1 is commonly detected at parietal, central, and frontal sites; whereas P2 shows distributions centring around fronto-central and occipito-parietal regions, which tends to produce a maxima at the vertex. According to the grand mean waveforms (presented as Figures 8.5 – 8.12, in Results) both N1 and P2 show fronto-central maximas. As such, analyses for both components were constrained to include only Fz and Cz. This resulted in analyses involving N1 and P2 data containing an additional two-level factor: Site: Fz and Cz.

All of these initial analyses were identical for both amplitude and latency data. Huynh-Feldt corrections were applied, where appropriate, to control for any violations of sphericity. Tukey's HSD post-hoc tests were conducted to clarify the simple effects of significant interactions, and main effects, where necessary. All statistical tests were considered significant at alpha .05.

Switch-Cueing

Data from psychophysiological dependent measures associated with task-cueing were analysed by individual 4 [Group] x 2 (Task) mixed ANOVAs. As was the case with task-execution analyses, P3 and N2 were analysed only at Pz and Fz, respectively; N1 and P2 analyses included an additional factor: Site: Fz and Cz. There were no behavioural dependent measures for the switch-cueing segment of the present experiment.

All of these initial analyses were identical for both amplitude and latency data. Huynh-Feldt corrections were applied, where appropriate, to control for any violations of sphericity. Tukey HSD post-hoc tests were conducted to clarify the simple effects of significant interactions and main effects where necessary. All statistical tests were considered significant at alpha .05.

Consideration of Local-Global Laterality Effects

The presence of left hemisphere bias in local processing and a right hemisphere bias in global processing in the visual domain is well established (Weissman & Woldorff, 2005). As discussed earlier in the present section, the stimuli employed in the current experiment were not expected to produce the laterality effects sometimes evident in ERP measures of local-global experimental paradigms. Nevertheless, the prospect of such hemispheric asymmetry warranted consideration with regard to ERP analysis.

There is inconsistency in the ERP literature around selective attention specific hemispheric asymmetry. While effects involving N1, N2 and P3 have been found in some studies (e.g., Heinze, Johannes, Münte, & Mangun, 1994; Proverbio et al., 1998; Yamaguchi, Yamagata & Kobayashi, 2000), these have been absent in others (e.g., Han, Fan, Chen & Zhuo, 1997; Heinze, Hinrichs, Scholz, Burchert & Mangun, 1998; Matthews & Martin, 2009).

Despite these conflicting results, there has been some consistency in the location of hemispheric asymmetries in ERP studies. These have typically been observed at occipito-temporal and/or temporo-parietal regions (Han et al., 2002; Weissman & Woldorff, 2005). These regions are at the cusp of the electrode array used to collect the EEG data in present experiment. Given this, the lack of definitive ERP effects in previous research, and the lack of importance of hemispheric asymmetry to the aims of the research, it was decided not to investigate effects involving hemispheric asymmetry in the present experiment. Hence, ERP analyses were constrained to midline sites.

Results

As mentioned earlier, in the interests of focus and brevity only effects of theoretical significance to the present study have been reported. As such, the reporting of ERP results have largely been constrained to group effects. Whereas all main effects for group were reported, interactions involving group are reported only when these achieved or approached statistical significance. Three exceptions to this have been made. These involve main effects that were hypothesised for the purpose of validation in the form of replication of effects from previous research.

Behavioural Data

Raw data were participants' individual response times on correctly performed trials and accuracy scores. Response times (in milliseconds) were converted to means, and correct responses to percentages.

Response Latency

The initial Group x Paradigm x Task x Trial mixed ANOVA indicated the main effect for Group was non-significant, $F(3,53)=0.380$, MSE=213655, $p=.768$. Nevertheless, Group was found to interact significantly with Paradigm, $F(3,53)=3.056$, MSE=6017, $p=.036$, $\eta^2=.146$. Whereas post-hoc analysis indicated no significant simple effects, the graph of the interaction presented as Figure 8.1 provides some indication of the differences likely to have driven the significant interaction. Overall, the Medium Trait-Anxiety group appeared to respond faster than all other groups, which showed relatively comparable response latencies. Whereas this pattern fits the optimal arousal for performance effect commonly referred to as the Yerkes-Dodson Law (Teigen, 1994), the absence of a significant main effect for group allows this no credibility. Groups did, however, show variation in response latency across the Paradigms. Whereas the Medium Trait-Anxiety and Repressor groups appear to have performed faster within the Task-Cueing paradigm, it appears the Low Trait-Anxiety group performed slower, compared to the Alternating-Runs paradigm.

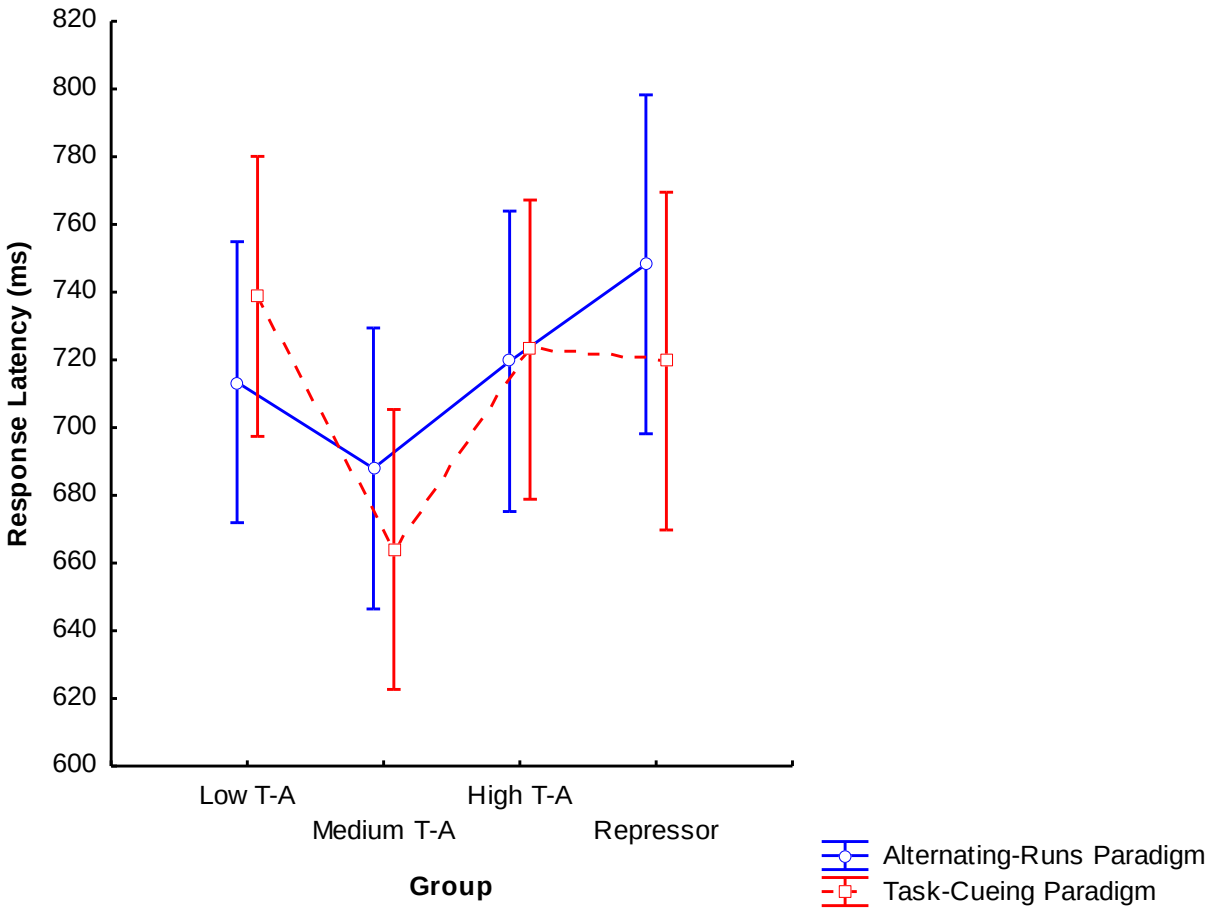

Figure 8.1. Mean response latency for each of the four groups for both paradigms (vertical bars denote SEM).

Paradigm was also found to interact significantly with Trial type, $F(3,53)=4.65$, MSE=3406, $p=.036$, $\eta^2=.083$. Again, post-hoc analysis indicated no significant simple effects. Inspection of Figure 8.2 suggests that, whereas response latency to Switch trials was longer within the Alternating-Runs than the Task-Cueing paradigm, response latency to Switch trials did not differ across the paradigms. Further, Figure 8.2 provides a clear illustration of the particularly powerful, significant, main effect for Trial $F(3,53)=164.44$, MSE=15345, $p<.001$, $\eta^2=.756$, whereby response latency to Switch trials ($M=789.58$, $SEM=26.56$) was far greater than that to Repeat trials ($M=639.06$,

SEM=17.97). This switch-cost effect demonstrates the success of the task-switching manipulation in both the Alternating-Runs and Task-Cueing paradigms.

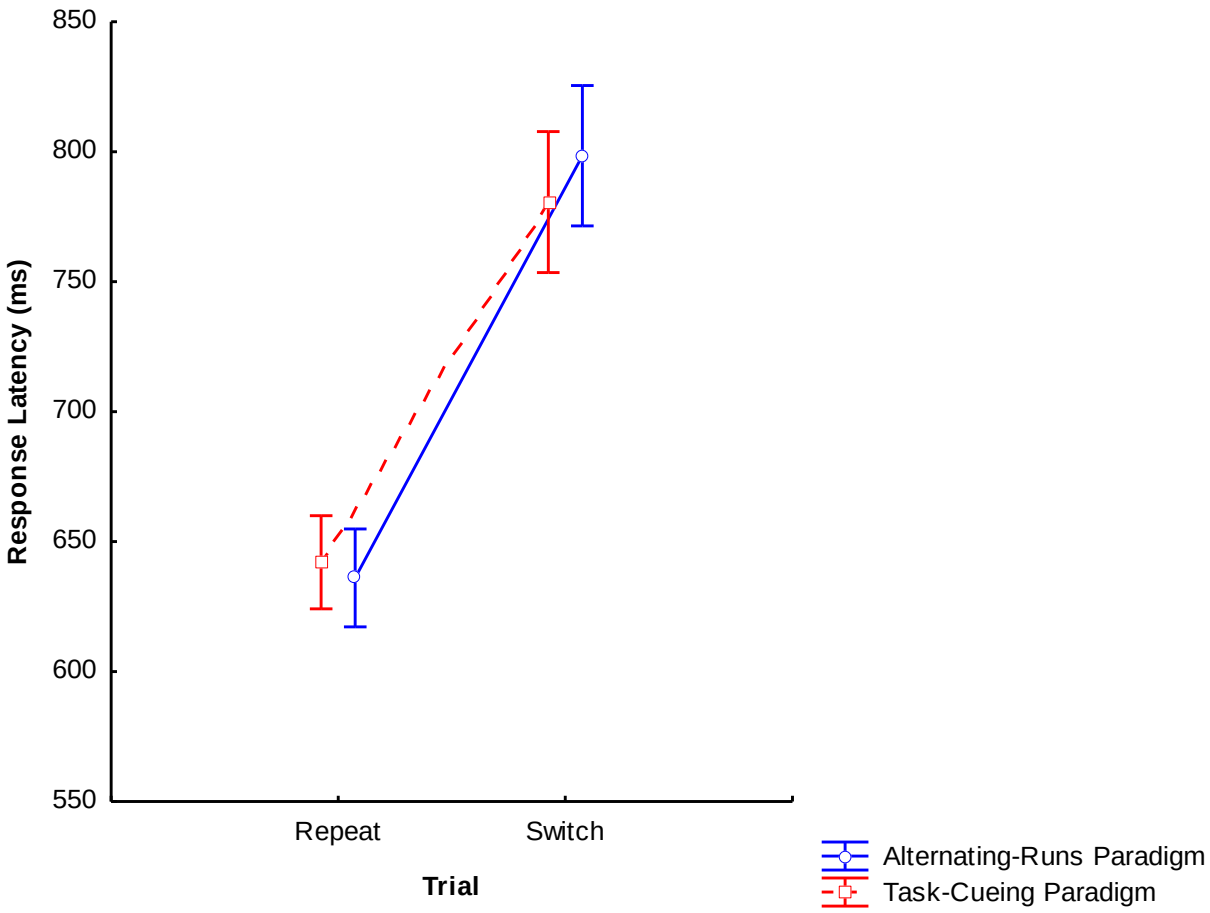

Figure 8.2. Mean response latency for both trial types across both paradigms (vertical bars denote SEM).

Response Accuracy

The initial Group x Paradigm x Task x Trial mixed ANOVA showed the main effect for Group not to be significant, $F(3,53)=0.33$, MSE=207, $p=.803$. The main effect for Paradigm was significant, $F(1,53)=7.22$, MSE=40, $p=.010$, $\eta^2=.118$; and the main effect for Task approached significance, $F(1,53)=3.87$, MSE=21, $p=.054$, $\eta^2=.067$. These effects were, however, subsumed by the significant Group x Paradigm x Task

interaction, $F(3,53)=4.03$, MSE=19, $p=.012$, $\eta^2=.186$ (see Figure 8.3). Post-hoc tests revealed the source of this interaction to be differential performance by the Repressor group on the Global task depending on the Paradigm. As illustrated in the right-side panel of Figure 8.3, Repressors performed the Global task with greater accuracy in the Task-Cueing paradigm (M=91.86, SEM=1.56), than in the Alternating-runs paradigm (M=87.07, SEM=2.11). Looking to the left-side panel in Figure 8.3, a similar effect is apparent for the Low and Medium Trait-Anxiety groups when performing the Local task. Whereas these effects were likely to have contributed to the significant interaction, they did not achieve significance in post-hoc testing.

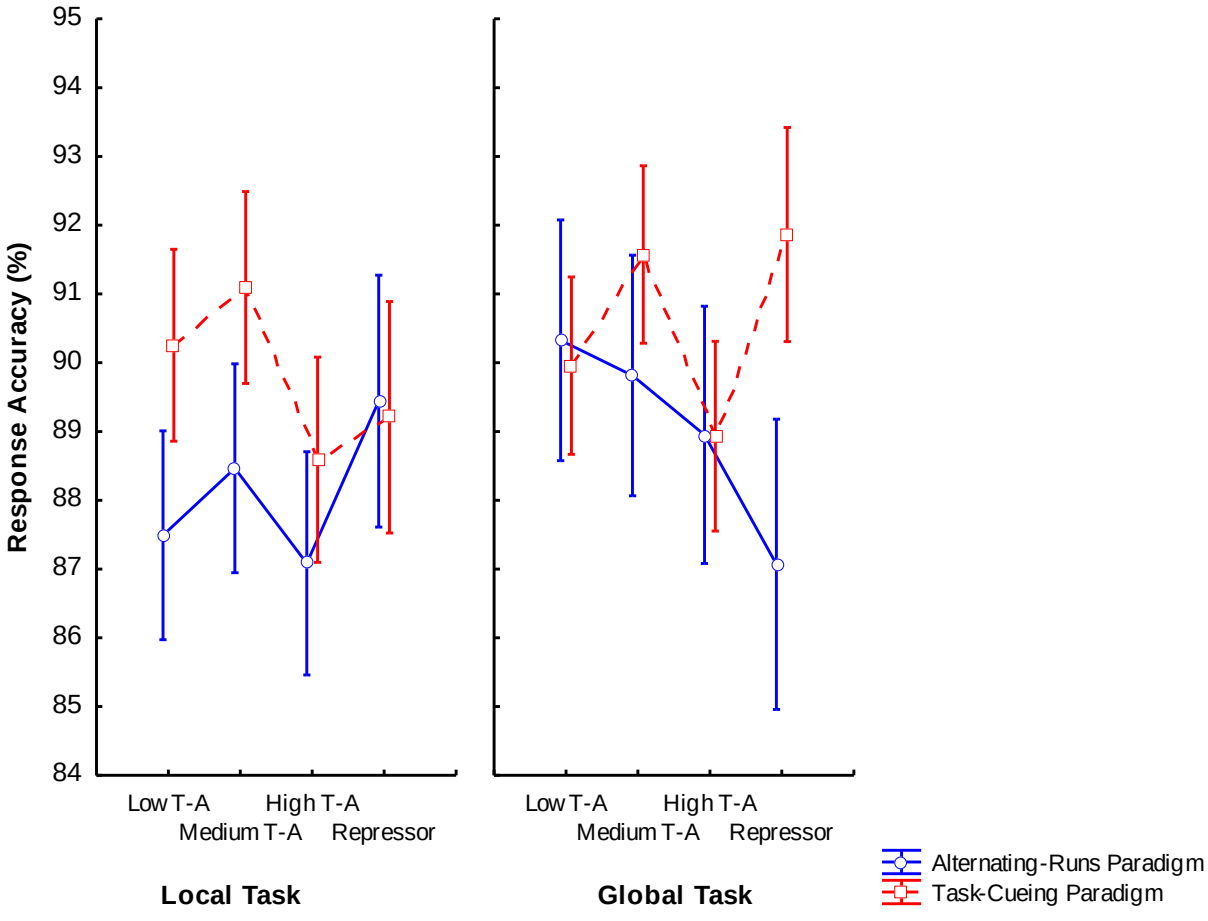

Figure 8.3. Mean response accuracy for each of the four groups, across both paradigms, for both tasks (vertical bars denote SEM).

Paradigm was also found to interact significantly with Trial, $F(3,53)=4.46$, MSE=15, $p=.040$, $\eta^2=.073$. Post-hoc analysis revealed all effects to be significant, with the exception of Repeat trials between the Alternating-Runs and Task-Cueing paradigms. As can be seen in Figure 8.4, response accuracy to Repeat trials was significantly greater than Switch trials. While mean accuracy percentage did not differ significantly between the Alternating-Runs and Task-Cueing paradigms for Repeat trials (M=91.05, SEM=0.78, and M=91.87, SEM=0.55, respectively), this was not the case for Switch trials. Mean response accuracy percentage to Switch trials in the Task-Cueing paradigm (M=88.50, SEM=0.92) was significantly greater than that in the Alternating-Runs paradigm (M=86.11, SEM=0.98). These results indicate that overall, and as expected, participants found switch trials more difficult than repeat trials – the switch cost effect. This switch cost was more prominent in the Alternating-Runs paradigm, where switches were more predictable. This predictability, however, did not facilitate accuracy.

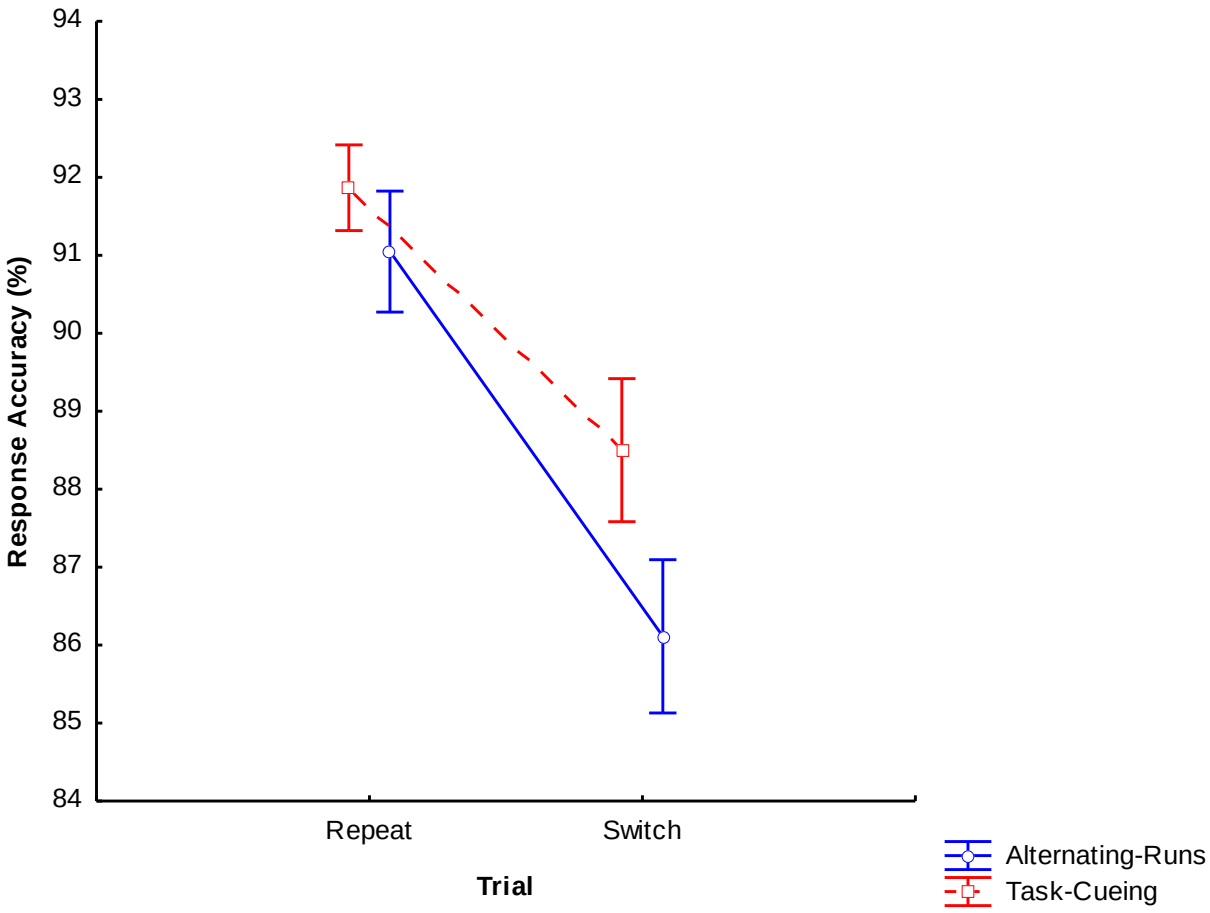

Figure 8.4. Mean response accuracy for both trial types across both paradigms (vertical bars denote SEM).

ERP Data

Figure 8.5 contains grand mean waveforms for cues from the Task-Cueing paradigm, along with Switch and Repeat trials – collapsed across both Paradigms – with all three waveforms collapsed across both Local and Global tasks, and each of the four groups. Grand mean waveforms for each of the four Groups are presented for Repeat trials and Switch trials in Figure 8.6. The figure following these, Figure 8.7, allows for comparison of Switch and Repeat trials within Alternating-Runs and Task-Cueing paradigms. Local-Global comparisons of Repeat trials, Switch trials and Switch-Cues are presented in Figure 8.8. The final graph in the present series relates specifically to the Task-Cueing

paradigm. Figure 8.9 contains the grand mean waveforms for switch cues, for each of the four groups, across both local and global tasks, within the task-cueing paradigm. The grand mean waveforms presented in each of these figures are scaled consistently. Whereas these figures show ERPs for midline sites only, full arrays are appended for inspection (see Appendices H, I, J, K, L, M, N and O).

Presented in Figure 8.5 are the grand mean waveforms for task cues from the Task-Cueing paradigm, along with all switch and repetition trials. Focussing on the midline sites, the N1 component appears to be largest at frontal sites, followed by central sites, and least prominent at parietal sites. As expected, N1 peak latency appears to increase from anterior to posterior sites. The P2 component is maximal at frontal and central sites. A curious cleft in the component is apparent for all three event types at Pz, with subtle evidence of this at Cz, also. As expected, N2 is maximal frontally, and P3 maximal parietally. Across all sites, amplitudes tended to be greater for Repeat trials than Switch trials, with task cues generally eliciting the largest amplitudes of the three event types.

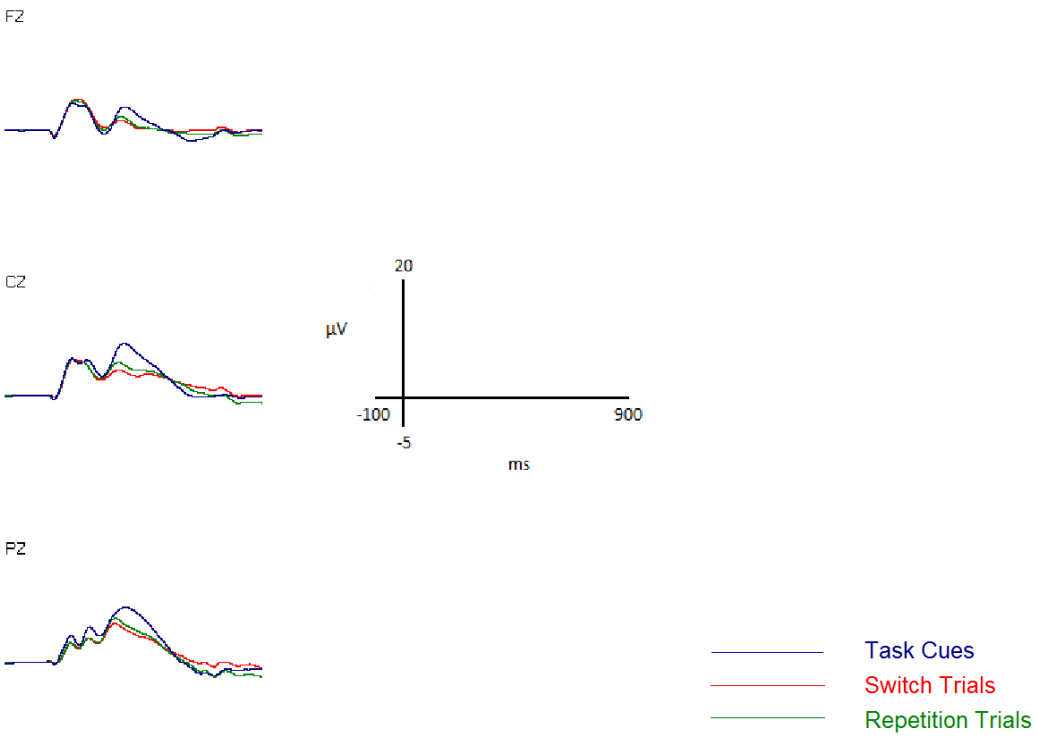

Figure 8.5. Grand mean waveforms for task-switching cues, switching trials, and repetition trials, collapsed across both, local and global tasks, and each of the four groups, for the task-cueing paradigm.

Figure 8.6 shows the grand mean waveforms for Repeat trials for each of the four groups, across all conditions. At the midline sites, the fronto-centrally maximal N1 appears to show the Repressor group as having produced the largest component. The High Trait-Anxiety group appears to have produced the next largest N1, with those produced by the Medium and Low Trait-Anxiety groups being lowest. The P2 component was also maximal fronto-centrally. Whereas P2 produced by the Low and Medium Trait-Anxiety groups are almost identical at these sites, both appear to peak much higher, and later, than those produced by the High Trait-Anxiety and Repressor groups, with the Repressor group clearly producing the lowest P2 amplitude. This pattern changes somewhat for the N2 component. At Fz, whereas the Low Trait-Anxiety group produced the lowest N2, and the Repressor group the highest, those for the

Medium and High Trait-Anxiety groups intermediated these quite similarly. Looking now to Pz, the P3 components produced by the Low and Medium Trait-Anxiety groups were of similar amplitude, however, the former appears to have peaked earlier. The P3 components produced by the High Trait-Anxiety and Repressor groups were both markedly lower than the former two, with that produced by the High Trait-Anxiety group clearly being the lowest of all.

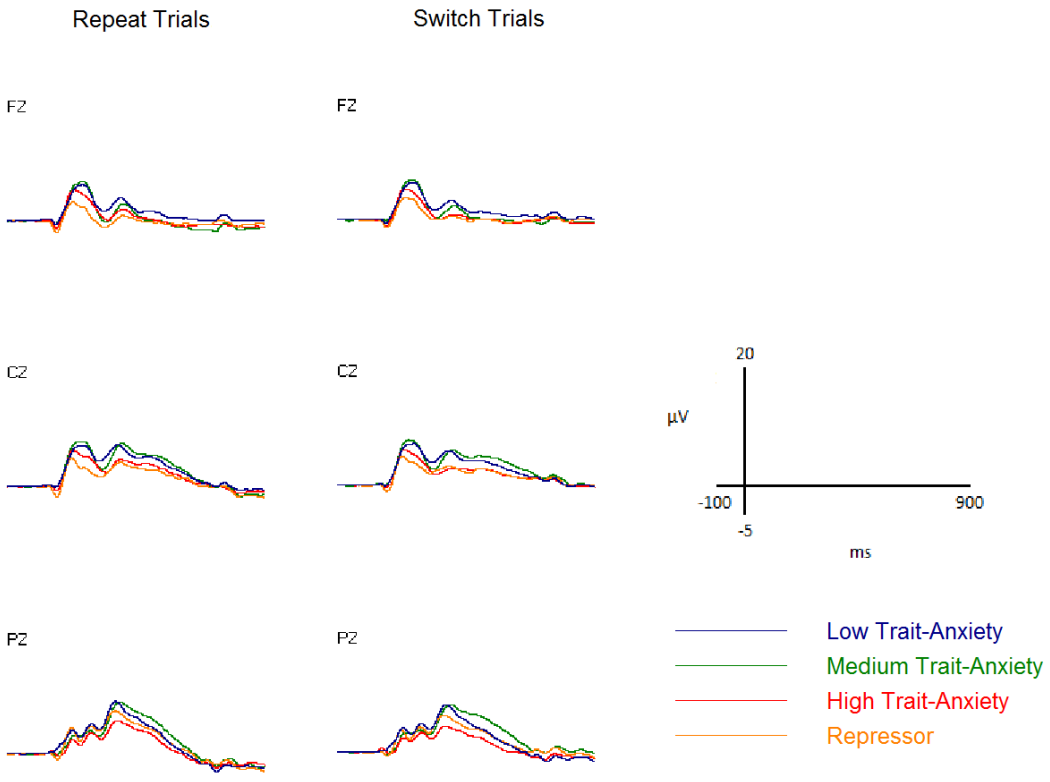

Figure 8.6. Grand mean waveforms for repetition trials and switch trials for each of the four groups, across all conditions.

Remaining on Figure 8.6, much similarity can be seen between the grand mean waveforms for Switch trials for each of the four groups, and those for Repeat trials (described directly above). Differences are, nonetheless, apparent. The most pervasive of these was the global reduction of N1 and P3 amplitudes to Switch trials compared to

Repeat trials. Focussing on group differences at the midline sites, modulation of N1 at Fz and Cz is apparent for the Repressor and High Trait-Anxiety groups. At Fz, the Repressor group produced a larger P2 along with a markedly reduced N2. Moving to Pz, P3 was lower to Switch trials for all Groups and this was particularly the case for the High Trait-Anxiety and Repressor groups.

Figure 8.7 shows the grand mean waveforms for Repeat and Switch trials, for both the Alternating-Runs and Task-Cueing paradigms. Beginning with the comparison of Repeat trials across both Paradigms, Figure 8.7 shows there was almost no divergence between paradigms on the components of interest. Inter-Paradigm differences were apparent when Switch trials were compared, however. Figure 8.7 shows a marked reduction in N1 for both Paradigms at Cz. Remaining at Cz, relative to Repeat trials, P2 for Switch trials was larger and earlier within the Task-Cueing paradigm, whereas the Alternating-Runs paradigm elicited a lower, later P2 at Cz. The case was similar at Fz, where P2 to Switch trials within the Task-Cueing paradigm was again larger and earlier than Repeat trials; although Switch trials within the Alternating-Runs paradigm only appeared to peak later than corresponding Repeat trials. Remaining at Fz, the N2 to Switch trials occurred later within both paradigms compared to Repeat trials, with Switch trials also showing attenuated N2 within the Alternating-Runs paradigm. Moving to Pz, compared to Repeat trials, P3 to Switch trials was lower and peaked earlier - though this effect was less apparent in the Task-Cueing paradigm.

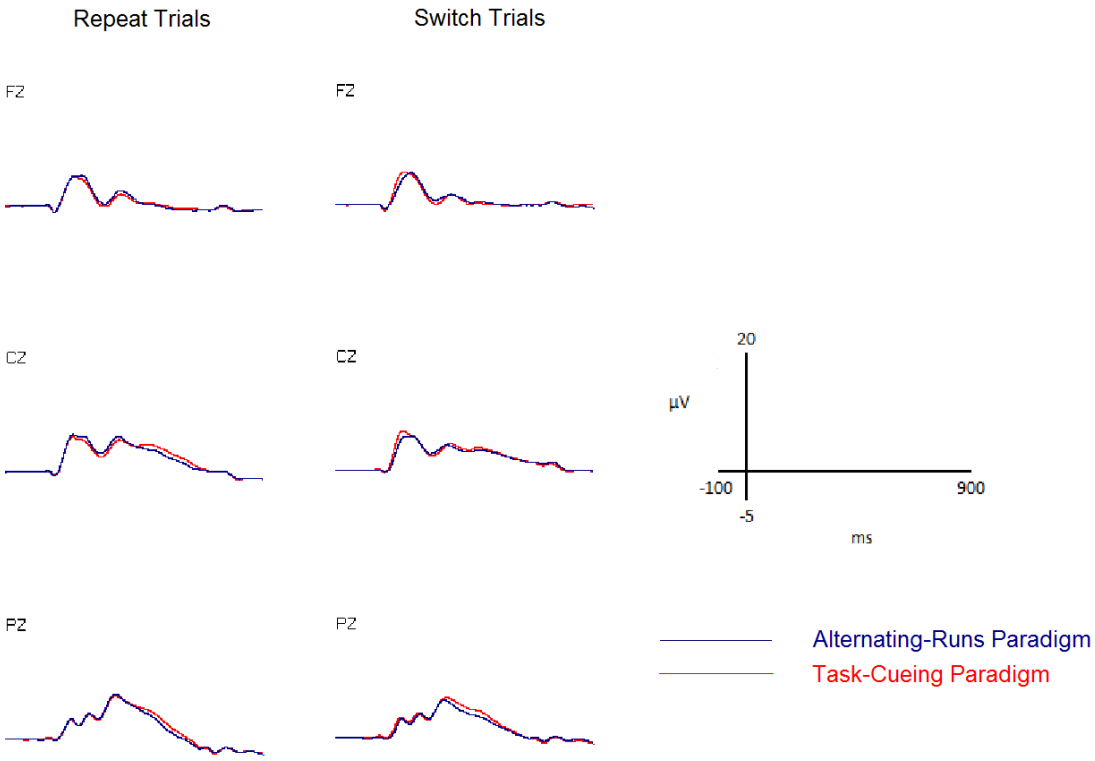

Figure 8.7. Grand mean waveforms for repeat trials and switch trials, for both the alternating-runs and task-cueing paradigms.

Comparison between the Local and Global tasks on grand mean waveforms for Repeat trials, Switch trials and Task-Cues are presented in Figure 8.8. Looking across the first two panels, as expected, the components of interest showed little evidence of sensitivity to Local-Global effects. For N1 to Repeat trials, the waveforms for the Local and Global tasks are virtually indistinguishable at the midline. Looking to Cz, whereas the P2 component appears slightly larger within the Global, this difference is barely discernable at Fz. Remaining at Fz, Repeat trials within the Global task appear to have produced a slightly greater N2 than those within the Local task, as was similarly the case for P3 at the Pz site. Moving now to comparison between the Local and Global tasks for Switch trials, a slight, general attenuation of N1 can be seen. The P2 elicited within the Local task appears to have increased slightly at both Fz and Cz, for Switch trials compared to Repeat trials. The opposite appears to be the case for N2, however,

whereby a decrease in amplitude within the Local task is apparent at Fz, relative to Repeat trials. At Pz, whereas P3 to Switch trials was lower across both Paradigms, compared to Repeat trials, this was particularly so within the Local task.

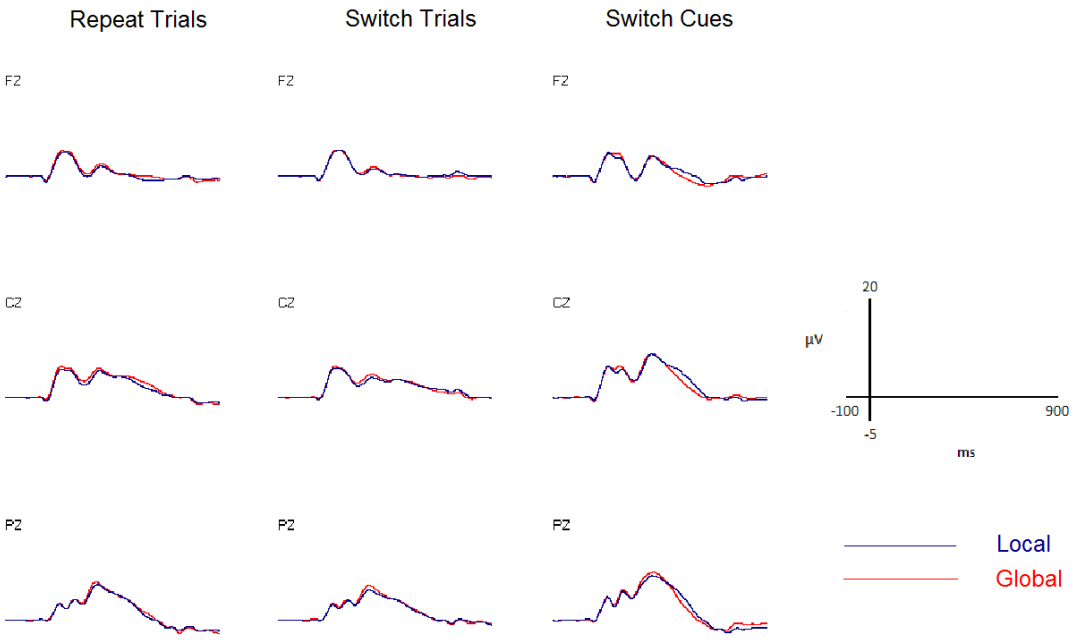

Figure 8.8. Grand mean waveforms for repetition trials, switch trials and switch-cues, for both local and global tasks, within the task-cueing paradigm.

The final panel of Figure 8.8 contains the grand mean waveforms produced in response to Switch Cues, for both Local and Global tasks; each of which has been collapsed across the four Groups. Consistent with previous grand means, N1 and P2 show fronto-central maximas, with N2 maximal at Fz and P3 at Pz. As with Figure 8.5, the cloven P2 apparent at Pz features again at Cz, and may be evident for Local Cues at Fz. Overall, Cues indicating the Global task appear to have elicited a more persistent P2,

and a slightly larger P3 that remitted earlier to that elicited by Cues indicating the Local task.

Comparison between each of the four Groups on grand mean waveforms to Switch Cues, collapsed across both the Local and Global Tasks, is presented in Figure 8.9. Focussing on the midline sites, N1 produced by the Repressor group appears to be markedly larger than each of the other three Groups at Fz and Cz, which show little divergence between them. For the fronto-central P2 component, the Low and Medium Trait-Anxiety groups were closely matched and showed little disparity across Fz and Cz. In comparison to these, P2 produced by the High Trait-Anxiety group peaked higher and earlier, whereas P2 produced by the Repressor group peaked lower and earlier. Further, the Repressor and High Trait-Anxiety groups showed more of the cleft in P2 at Cz than the Low and Medium Trait-Anxiety groups. At Fz, the N2 was clearly largest for the Repressor group, followed by the Medium Trait-Anxiety group, with the smallest N2 being produced by the Low and High Trait-Anxiety groups. For the P3 component, group differences at Pz were moderate. Repressors produced the lowest P3, followed by the Low Trait-Anxiety, then the High Trait-Anxiety group, with the Medium Trait-Anxiety group producing the highest P3, which also persisted markedly longer than the other three groups. Across all groups, peak latency appeared to increase as a function of peak amplitude.

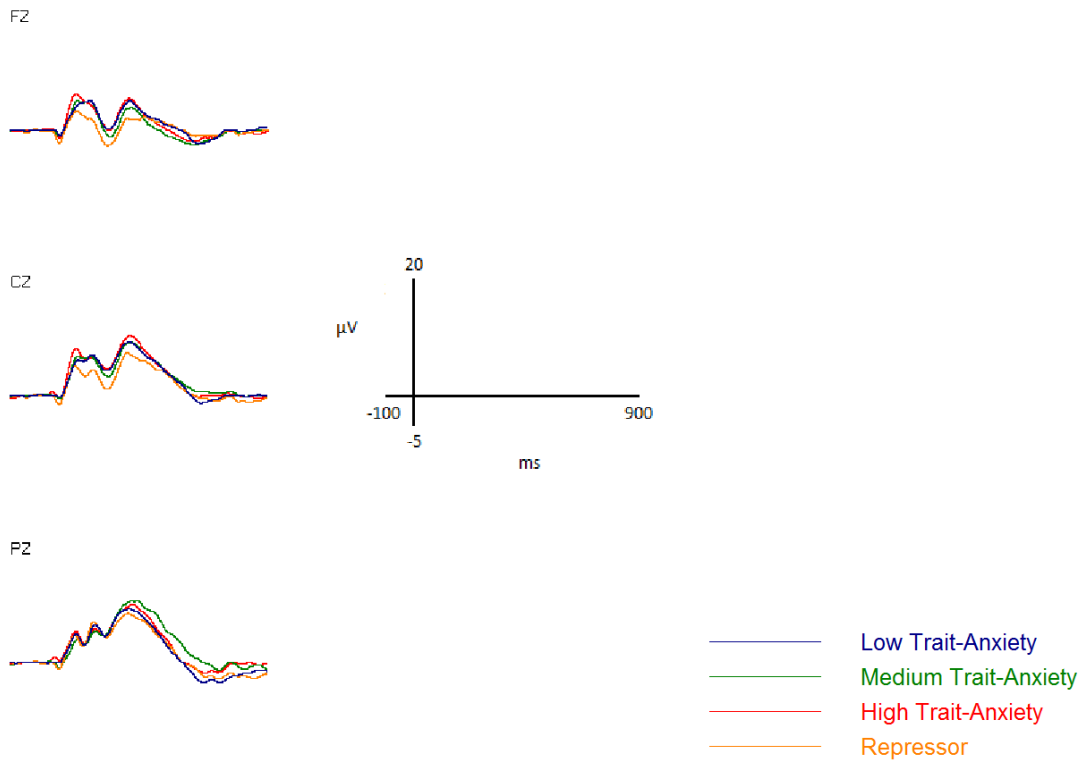

Figure 8.9. Grand mean waveforms for switch cues, for each of the four groups, across both local and global tasks, within the task-cueing paradigm.

Task-Execution Effects

Raw data were participants' EEG to correctly performed trials. These were processed as described in the Method section. Each participant's mean peak amplitude (μV) and latency (ms) for the N1, P2, N2 and P3 components were initially subjected to 4 [Group] x 2 (Paradigm) x 2 (Task) x 2 (Trial) mixed ANOVA, at selected Sagittal sites, according to the dictates of the respective hypotheses and the topographical distributions of each component, as discussed earlier. Hence, P3 was analysed only at Pz, and N2 only at Fz; whereas P2 and N1 were both analysed at each of Fz, Cz and Pz.

N1 Amplitude

The Group x Paradigm x Task x Trial x Sagittal mixed ANOVA for N1 amplitude showed the main effect for Group as trending toward significance, $F(3,53)=2.43$,

MSE=50.94, p=.076 , η^2=.121. The greatest N1 amplitudes were produced by the Repressor group (M=-3.28, SEM=0.54), followed by the High Trait-Anxiety group (M=-2.48, SEM=0.48), and then the Medium (M=-1.76, SEM=0.45) and Low (M=-1.58, SEM=0.45) Trait-Anxiety groups. This pattern for increased N1 amplitude matches expectations of the relative behaviour of these groups with respect to arousal, vigilance, and motivation for early stimulus discrimination (and sensory/information gain toward downstream processing). Group was found to interact significantly with Paradigm and Sagittal, F(3,53)=3.69, MSE=0.95, p=.017, η^2=.166. Whereas post-hoc tests indicated no significant relevant effects, inspection of Figure 8.10 (below) shows that overall, N1 amplitude at Fz tended to be around 0.5 μV larger than that recorded at Pz. Further inspection of Figure 8.10 shows that the significant interaction was likely driven by the markedly low N1 amplitude produced by the High Trait-Anxiety group within the Task-Cueing paradigm relative to the Alternating-Runs paradigm, at Cz. Interestingly, Paradigm appeared to have very little effect on N1 amplitude produced by the Low Trait-Anxiety and Repressor groups. No other effects of interest for N1 amplitude reached significance.

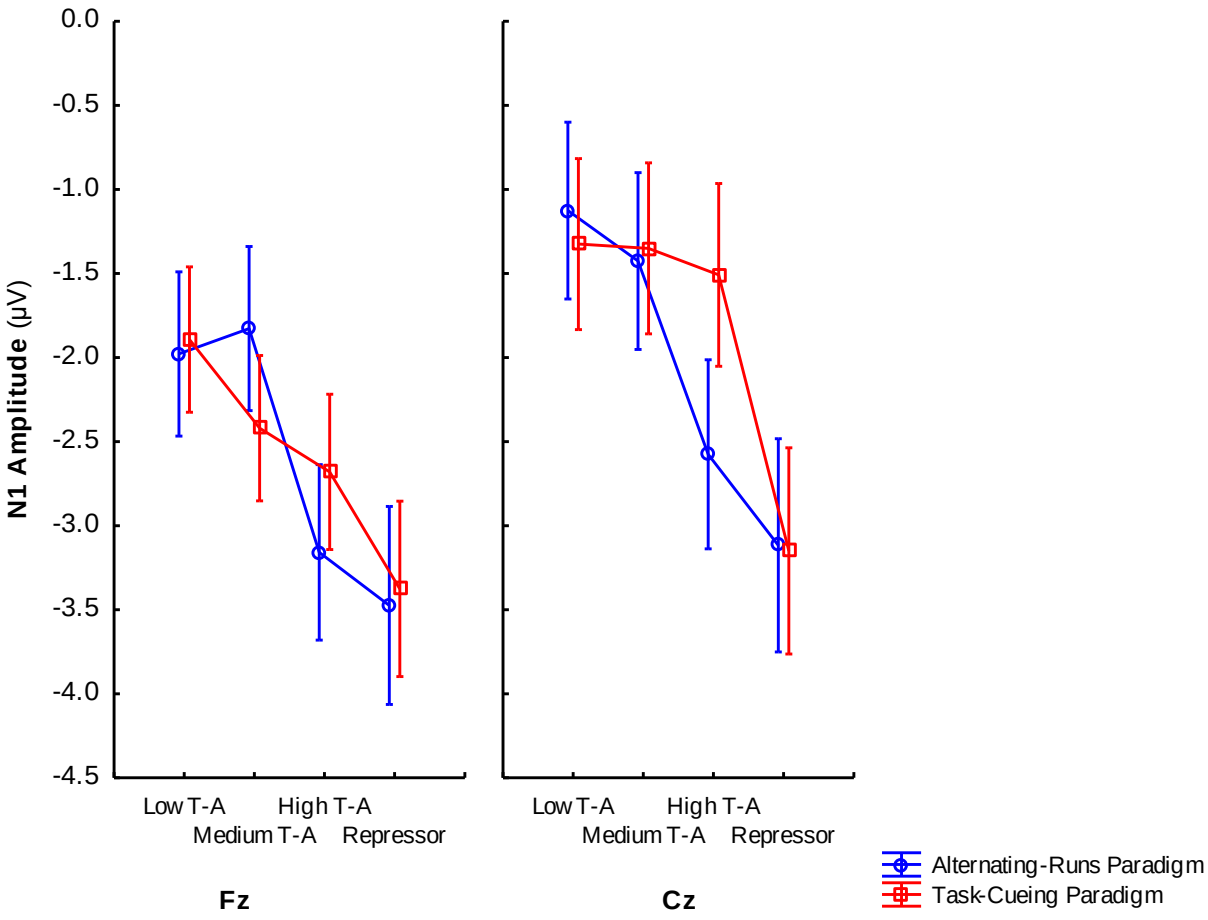

Figure 8.10. N1 amplitude for each of the four groups, at both sagittal sites, within both paradigms (vertical bars denote SEM).

N1 Latency

The initial Group x Paradigm x Task x Trial x Sagittal ANOVA for N1 Latency indicated the main effect for Group was not significant, $F(3,53)=0.07$, MSE=1225, $p=.974$. Group was, however, found to interact significantly with Paradigm and Trial, $F(3,53)=3.59$, MSE=58.00, $p=.020$, $\eta^2=.152$. The graph of this interaction, presented in Figure 8.11, shows that N1 tended to occur earlier within the Task-Cueing paradigm, compared to the Alternating-Runs paradigm. In the absence of significant post-hoc tests of relevance, the interaction appears to be driven by effects involving the Low Trait-Anxiety and Repressor groups. The most pronounced effect involves the speed of N1

related processing by the Low Trait-Anxiety group when performing Repeat trials. In relative terms, the N1-related processing by the Low Trait-Anxiety group appears to have peaked much earlier within the Alternating-Runs paradigm, and much later within the Task-Cueing paradigm. This pattern was nearly identical for the Repressor group; however, the magnitude of difference was lower, even with facilitation afforded by a marked decrease in N1 Latency on Switch trials within the Task-Cueing paradigm. This marked increase in the speed of N1-related processing by the Repressor group when performing Switch trials within the Task-Cueing paradigm is especially noteworthy. This is because, within the context of the present interaction, both the absolute slowest, and the absolute fastest N1-related processing were conducted by the Repressor group when performing Switch trials – within the Alternating-Runs, and Task-Cueing paradigms, respectively. This suggests that, for the Repressor group, the differing conditions between these paradigms effected either the delaying or expediting of N1-related processing associated with Task-Switching. Also, this indicates that the Low Trait-Anxiety group showed facilitated processing for Repeat trials in the Alternating-Runs paradigm, but retarded speed of processing in the Task-Cueing paradigm.

The factors of Group and Paradigm were also found to significantly interact with Task, $F(3,53)=2.80$, MSE=73.00, $p=.049$, $\eta^2=.137$. Post-hoc analysis indicated no significant relevant effects. Nevertheless, the graph of this interaction, presented in Figure 8.12, shows that the Latency of N1 produced by the Low Trait-Anxiety group was very consistent for each Task across both Paradigms. Conversely, N1 produced by the Medium and High Trait-Anxiety groups when performing the Global task peaked much earlier within the Task-Cueing paradigm than the Alternating-Runs paradigm. The Repressor group, similar to the Low Trait-Anxiety group, showed very little difference in Latency to the Global task across the Paradigms. In stark contrast to each of the other three groups, however, the Repressor group showed a markedly longer N1 processing time when performing trials in the Local, compared to the Global task, within the Alternating-Runs paradigm. In fact, this delayed latency represented the longest N1-related processing time of any Group in any condition within the present interaction. Taken in concert with the observation that Repressors' N1-related processing in the same condition within the Task-Cueing paradigm was very nearly the fastest within the

present interaction, this pattern matches closely with that observed in the previous interaction (see Figure 8.11). The previous interaction involved both Group and Paradigm, with the differentiating factor being Trial type.

Looking across the graphs representing the Group x Paradigm x Trial (Figure 8.11) and Group x Paradigm x Trial x Task (Figure 8.12), it is evident that, within the context of each of these interactions, that the slowest N1-related processing was performed by the Repressor group in the Switch and Local conditions, respectively – within the Alternating-Runs paradigm. Conversely, this effect was inverted within the Task-Cueing paradigm, whereby Repressors performed the fastest N1-related processing. Taken together, this pattern strongly suggests that, for the Repressor group, the differing conditions between these paradigms effected either the delaying or expediting of N1-related processing associated with Task-Switching and Local-Global processing and that the Low Trait-Anxiety Group is singularly impervious to the effect of Paradigm on Local-Global processing.

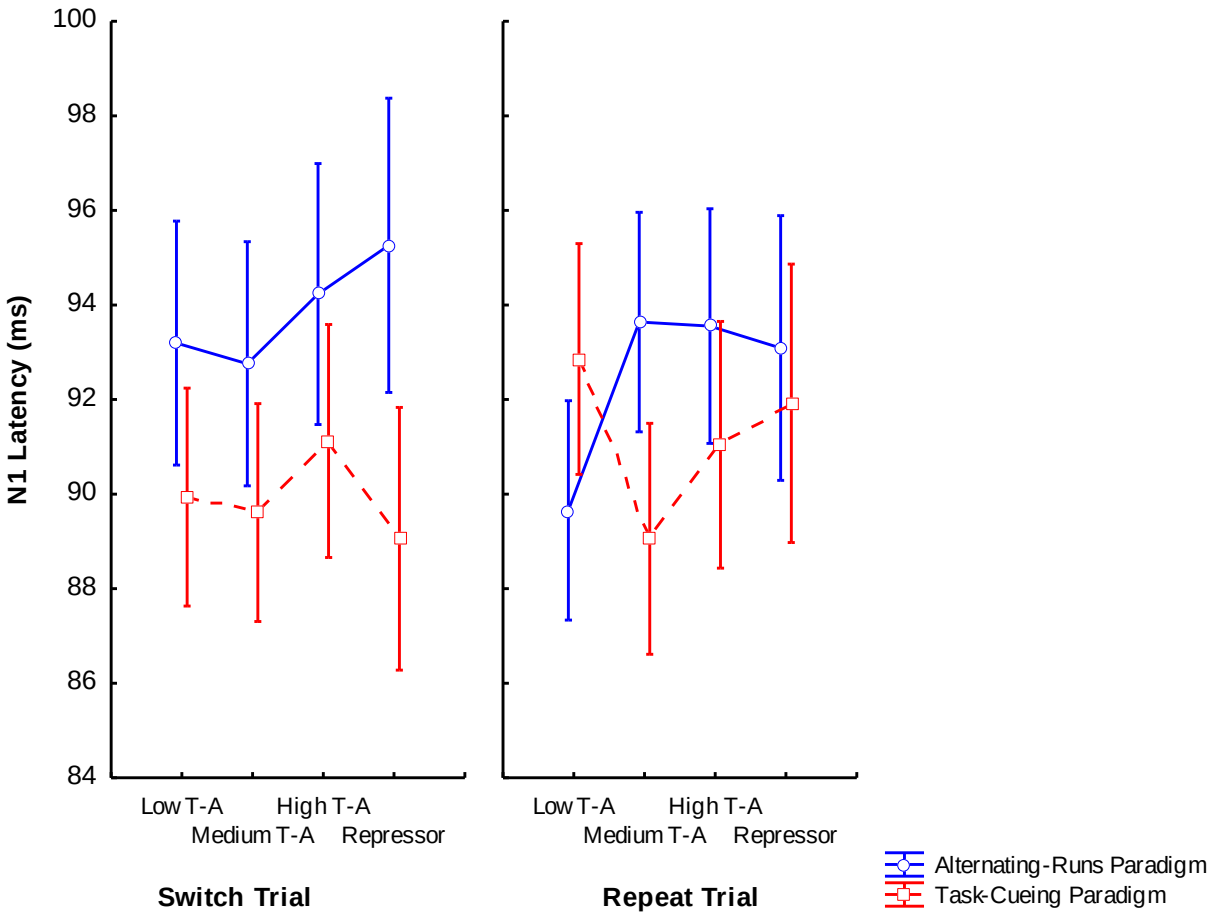

Figure 8.11. N1 latency for each of the four groups to both trial types, within both paradigms (vertical bars denote SEM).

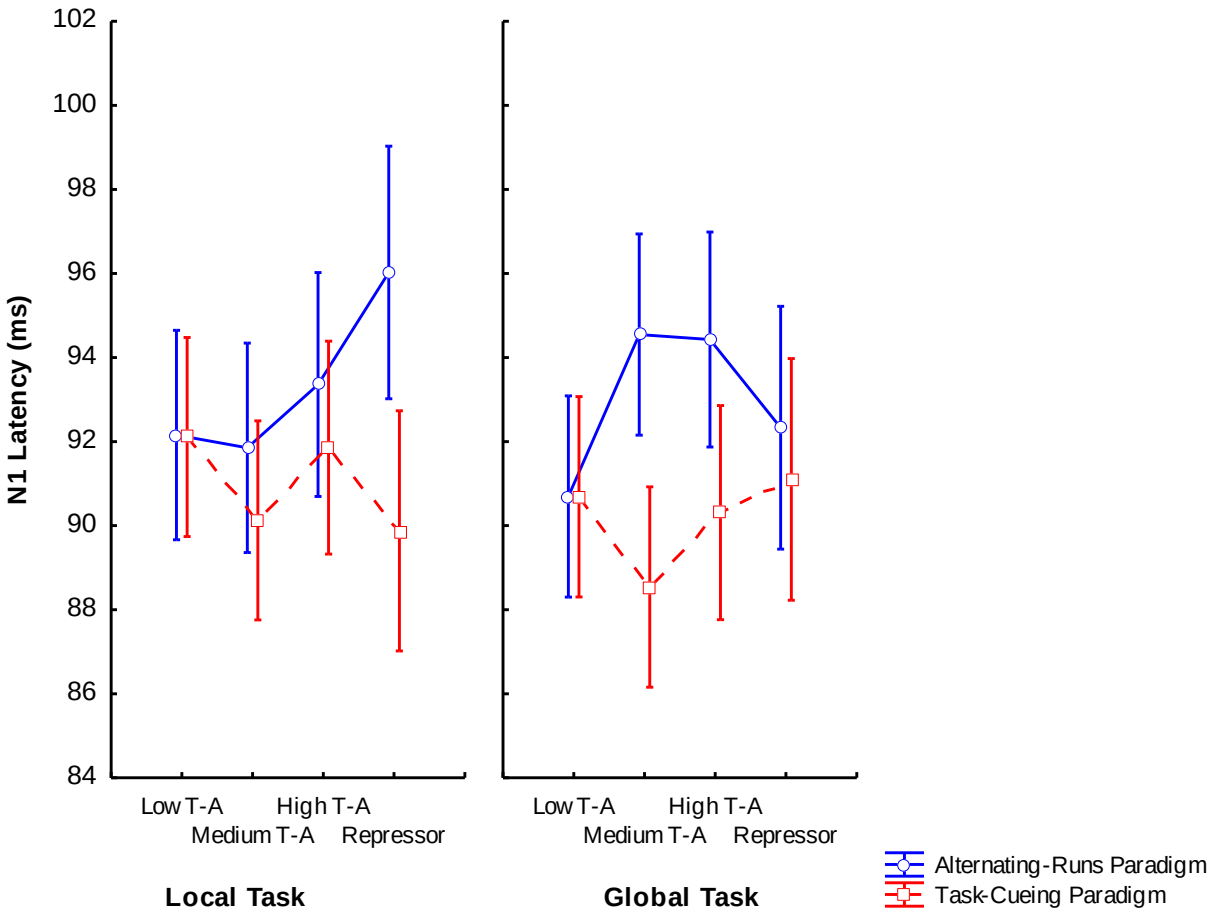

Figure 8.12. N1 latency for each of the four groups to both tasks, within both paradigms (vertical bars denote SEM).

P2 Amplitude

The Group x Paradigm x Task x Trial x Sagittal ANOVA for P2 amplitude showed the main effect for Group to be significant, $F(3,53)=3.26$, MSE=259.64, $p=.029$, $\eta^2=.159$. The Medium Trait-Anxiety group produced the largest P2 amplitude ($M=12.58$, $SEM=1.01$), followed by the Low ($M=11.49$, $SEM=1.01$), and then High ($M=10.34$, $SEM=1.08$) Trait-Anxiety groups, with the Repressor group producing the lowest mean amplitude ($M=7.82$, $SEM=1.22$). Post-hoc tests indicated that whereas P2 amplitude produced by the Repressor group was significantly lower than that produced

by the Medium Trait-Anxiety group (p=.020), the similar effect involving the Low Trait-Anxiety group merely trended toward significance (p=.105).

The interaction among Group, Task and Sagittal was found to border on significance, $F(3,53)=2.77$, MSE=1.41, p=.050, η^2=.109. Figure 8.13 shows that, overall, P2 amplitudes were lower at Fz than Pz. For the Global task, this difference was uniform for all groups, at approximately 2μV. For the Local task, a difference of approximately 1μV was uniform for each group, with the exception of the Repressor group, which retained the 2μV difference. In lieu of any significant post-hoc effects involving Group, it was surmised that this lower P2 amplitude produced by the Repressor group at Fz while performing the Local task drove the significant interaction.

The main effect for Trial type did not reach significance, $F(1,53)=0.303$, MSE=14.36, p=.585. Hence, the hypothesised effect for lower P2 amplitude to Switch compared to Repeat trials was not supported.

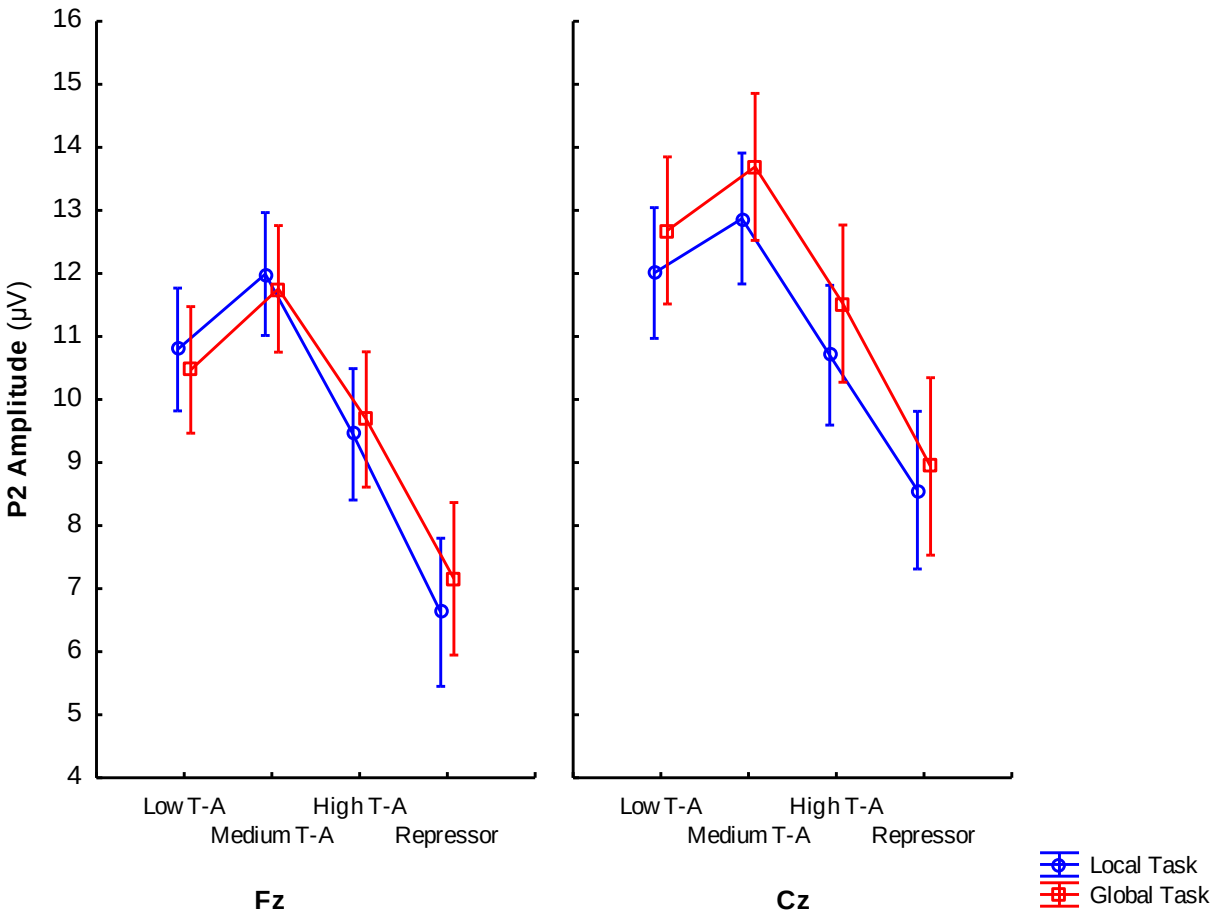

Figure 8.13. P2 amplitude for each of the four groups, at both sagittal sites, to both tasks (vertical bars denote SEM).

P2 Latency

The Group x Paradigm x Task x Trial x Sagittal ANOVA for P2 Latency showed the main effect for Group was not significant, $F(3,53)=1.96$, MSE=4181, $p=.132$. Nor was Group found to be involved in any significant interaction.

N2 Amplitude

The Group x Paradigm x Task x Trial analysis at Fz indicated the main effect for Group to be significant, $F(3,53)=4.09$, MSE=84.72, $p=.011$, $\eta^2=.188$. Group was also found to interact significantly with Paradigm and Trial, $F(3,53)=2.99$, MSE=3.75,

p=.039, η^2=.137. The representation of this interaction provided in Figure 8.14 shows that N2 amplitude tended to be slightly lower within the Alternating-Runs paradigm. Group differences were more apparent. The Low Trait-Anxiety group clearly produced the lowest N2 amplitude, and the Repressor group the highest. Intermediating these, however, the High Trait-Anxiety group appears to have produced slightly lower N2 than the Medium Trait-Anxiety group, overall. The significant interaction appears to have been driven by the variation in N2 produced by the Repressor group in the Alternating-Runs paradigm, with post-hoc testing showing the lower amplitude to Switch trials compared to Repeat trials being the only effect to approach significance (p=.101).

Also noteworthy was the Group x Paradigm x Task interaction, which trended toward significance, F(3,53)=2.32, MSE=3.90, p=.086, η^2=.116. Figure 8.15 shows little difference in overall amplitude between Paradigms. The profile of Group differences was similar to that in the previous interaction (see Figure 18.14), with the Low Trait-Anxiety group clearly producing the lowest N2 amplitude, and the Repressor group the highest. Somewhat more pronounced than the previous interaction, however, was the tendency for the High Trait-Anxiety group to produce lower N2 than the Medium Trait-Anxiety group. The single exception to this appeared within the Alternating-Runs paradigm, where the High Trait-Anxiety group produced a greater mean N2 than the Medium group when performing the Local task. In lieu of relevant significant post-hoc effects, this singularity appears to be the main driver of the current trend toward significance for the current interaction.

Looking across Figures 8.14 and 8.15, it can be seen why the only difference to reach significance in the post-hoc testing of the significant main effect, was for Repressors (M=-3.75, SEM=0.98) to produce greater mean N2 amplitude than the Low Trait-Anxiety group (M=0.52, SEM=0.81) (p=.008).

The main effect for Trial type was not found to be significant, F(1,53)=1.72, MSE=7.92, p=.196. As such, the hypothesised effect for greater N2 amplitude to Switch compared to Repeat trials was not supported.

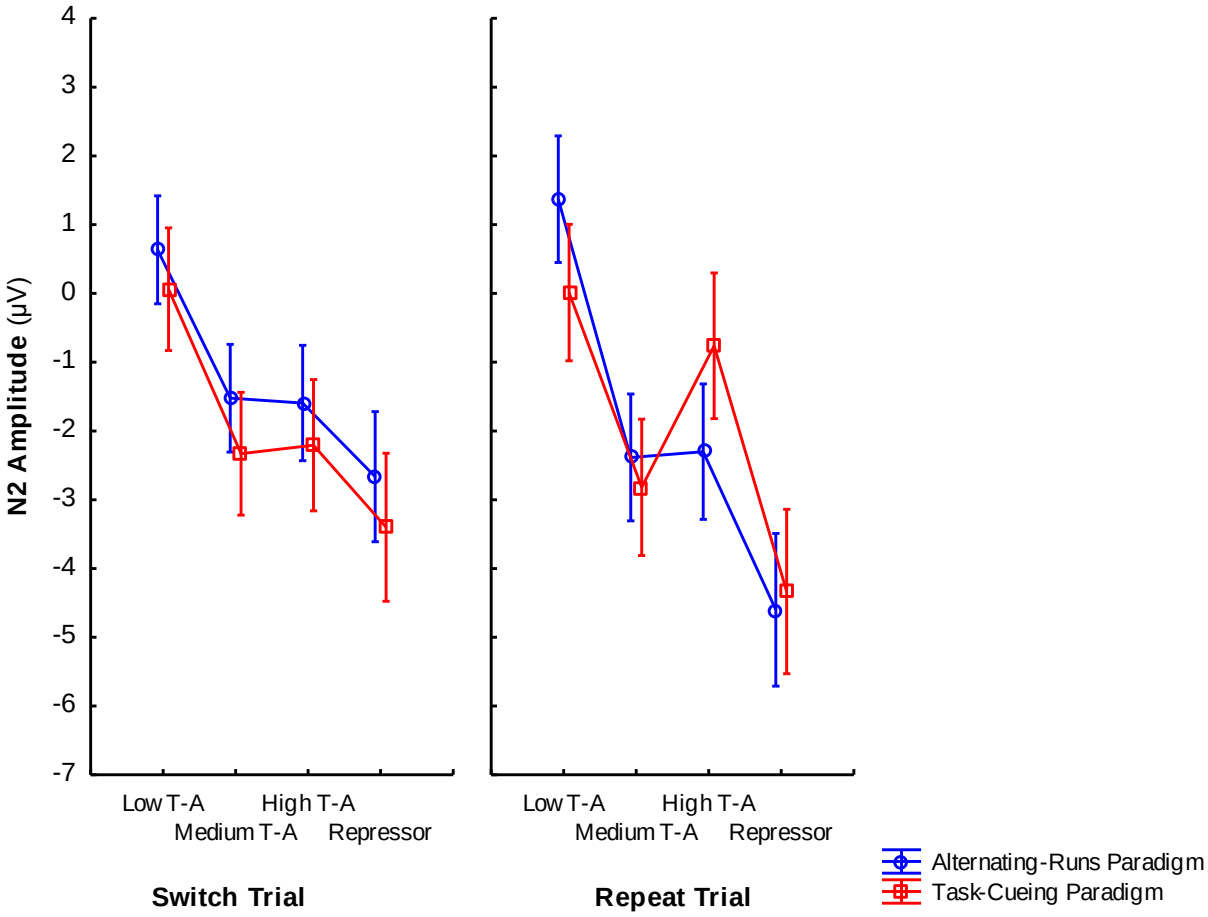

Figure 8.14. N2 amplitude for each of the four groups, for both trials, within both paradigms (vertical bars denote SEM).

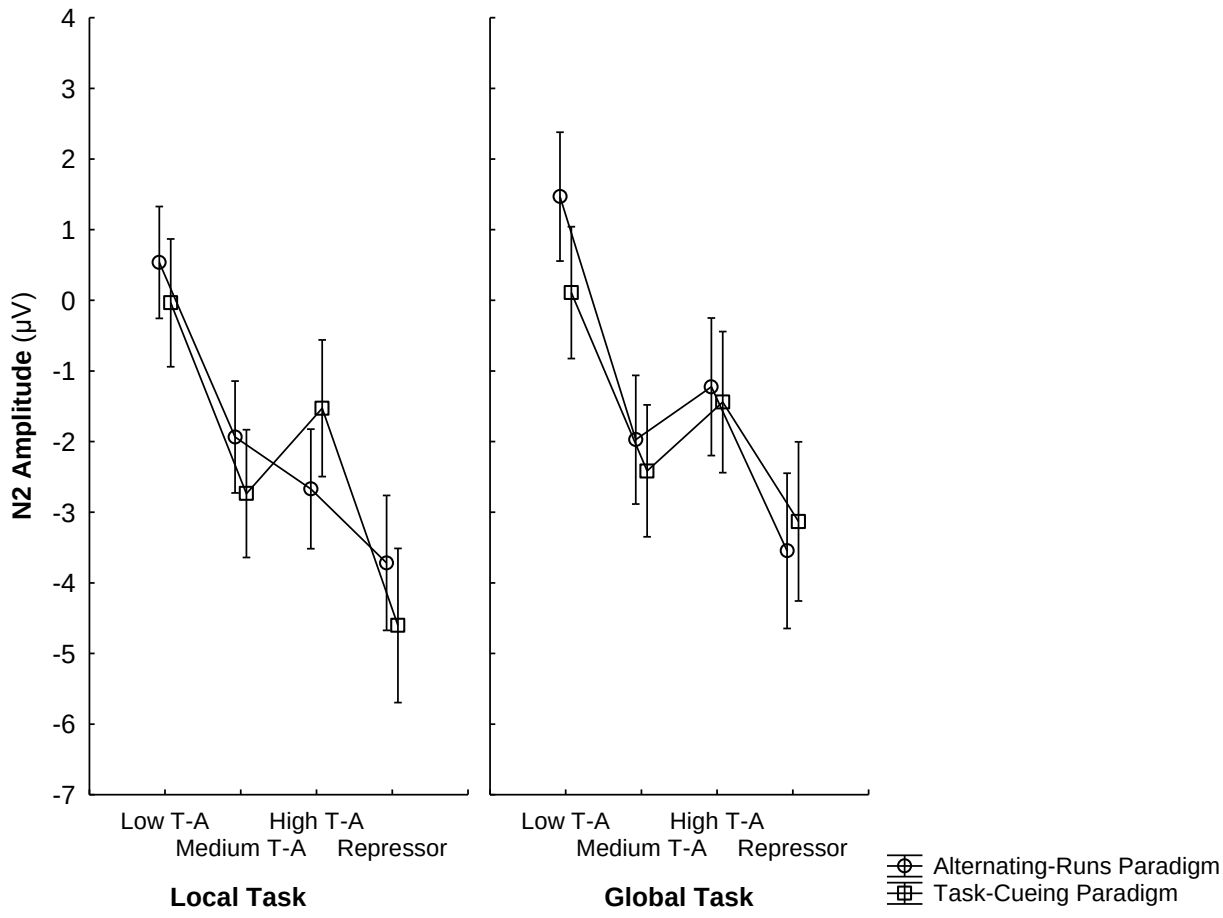

Figure 8.15. N2 amplitude for each of the four groups, to both tasks, within both paradigms (vertical bars denote SEM).

N2 Latency

The Group x Paradigm x Task x Trial analysis at Fz for N2 latency showed the main effect for Group to be non-significant, $F(3,53)=1.078$, MSE=5005.00, $p=.366$. Group was, however, involved in a significant interaction with Paradigm and Task, $F(3,53)=3.22$, MSE=385.00, $p=.030$, $\eta^2=.154$. Although none of the effects underlying this interaction were determined to be significant according to post-hoc analyses, Figure 8.16 allows observation of the relevant effects. Overall, N2 latencies appear to be slightly lower within the Task-Cueing paradigm, compared to the Alternating-Runs paradigm. Also, there is no clear pattern of differences in latency between the Local and

Global tasks. The overall pattern of group differences is for N2 to be produced earliest by the Low Trait-Anxiety and Repressor groups, with those produced by the Medium Trait-Anxiety group peaking slightly later. The latest peaks were clearly those produced by the High Trait-Anxiety group. The principal contributor to the significant interaction appears to be the discrepancy between mean latencies achieved by the Low Trait-Anxiety Group in the Task-Cueing Paradigm, where the N2 component appears to peak earlier on the Global Task, than the Local Task.

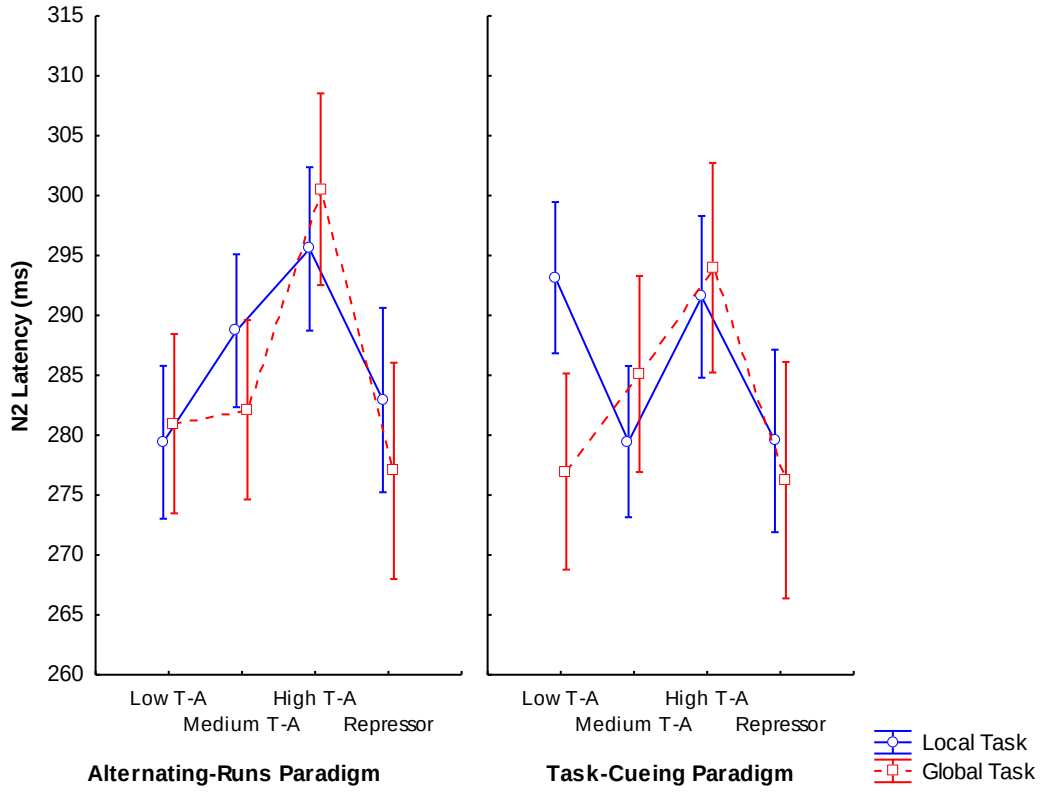

Figure 8.16. N2 latency for each of the four groups, within both paradigms, on both tasks (vertical bars denote SEM).

Group and Paradigm also trended toward interacting significantly with Trial, $F(3,53)=2.31$, MSE=406.00, $p=.087$, $\eta^2=.115$. The graph of this trend, presented as Figure 8.17, indicates that, overall, Group differences in N2 latency appeared reasonably

stable across both Trial and Paradigm. The Repressor group tended to produce slightly earlier N2 than the Medium Trait Anxiety group, which tended to be slightly earlier than the Low Trait-Anxiety group, with the High Trait-Anxiety group showing a clear, consistent, pattern of producing the latest N2. Within Group, the Switch trials showed virtually no difference in Latency across the Paradigms. The profile of between-Group differences observed for Switch trials was maintained for Repeat trials within the Task-Cueing paradigm, though with somewhat shorter Latencies, particularly for the High Trait-Anxiety group. There was, however, less maintenance of that between-Group profile for Repeat trials within the Alternating-Runs paradigm. Here, the Low Trait-Anxiety group showed a marked decrease in processing time. Not only was this N2 earlier than to the corresponding Repeat trials within the Task-Cueing paradigm, it was also the earliest produced by any Group within the context of the interaction. In contrast to this, the High Trait-Anxiety group appeared to produce somewhat later N2 than to the corresponding Repeat trials within the Task-Cueing paradigm.

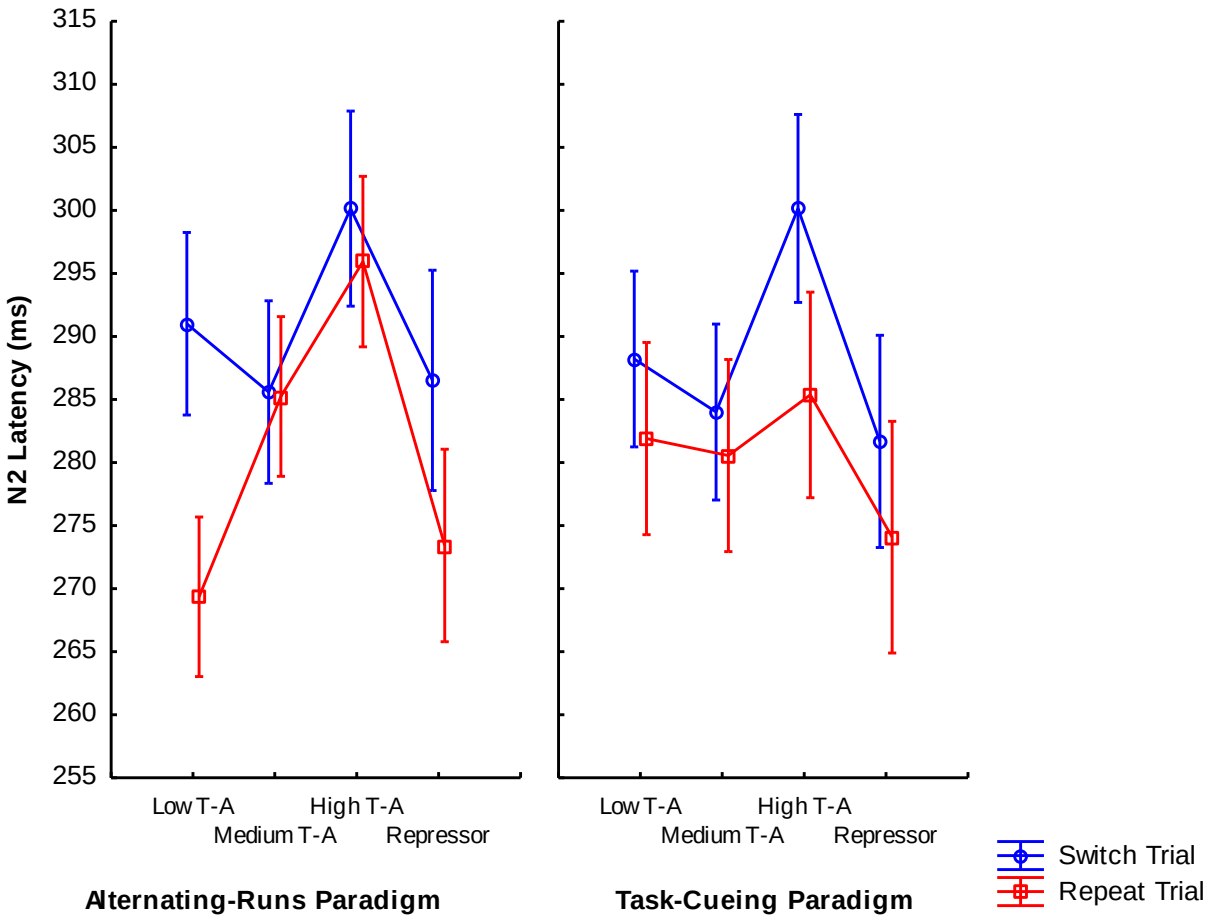

Figure 8.17. N2 latency for each of the four groups, for both trials, within both paradigms (vertical bars denote SEM).

P3 Amplitude

The initial Group x Paradigm x Task x Trial mixed ANOVA at Pz revealed the main effect for Group to be significant, $F(3,53)=3.12$, MSE=180.85, $p=.034$, $\eta^2=.150$. Notwithstanding higher order interactions, overall P3 amplitude appeared lowest for the High Trait-Anxiety group ($M=10.05$, $SEM=1.27$), followed by the Repressor group ($M=12.31$, $SEM=1.43$), then Low Trait-Anxiety group ($M=14.02$, $SEM=1.19$), with the highest P3 produced by the Medium Trait-Anxiety group ($M=15.07$, $SEM=1.19$). Post-hoc tests indicated only the difference between the High and Medium Trait-Anxiety groups to be significant ($p=.028$).

This main effect for Group was moderated by the significant Group x Paradigm interaction, $F(3,53)=4.17$, MSE=14.05, $p=.010$, $\eta^2=.187$. This Group x Paradigm interaction was modified further by the significant Group x Paradigm x Task x Trial interaction, $F(3,53)=3.54$, MSE=4.34, $p=.029$, $\eta^2=.147$. Post-hoc analysis showed no relevant effects to be significant. Nevertheless, the graphical representations of the interaction, presented in Figures 8.18a and 8.18b, allow observation of the effects of interest. Looking across all four panels, a trend is apparent for mean P3 amplitude to be slightly lower in response to the Local Task, compared to the Global Task

The expected effect for lower mean P3 amplitude to Switch Trials compared to Repeat Trials can be seen quite clearly in the Alternating-Runs Paradigm, presented as Figure 8.18a. When looking across both the left and right panels, consistency is evident at three levels: the profiles pattern of Group differences, the general concordance between Local and Global Tasks, and the effect for amplitudes to be around two microvolts lower in response to Switch Trials (left panel) than to Repeat Trials (right panel). While this is consistent with previous research, the overall absence of this effect in the Task-Cueing Paradigm, presented as Figure 8.18b, is contrary to expectations and previous research.

Two further effects of interest appear in the graphical representations of this complex interaction. Each of these relates to the way Group, specifically the Low Trait-Anxiety and Repressor Groups, interacts with Paradigm (note, the significant Group x Paradigm interaction was subsumed by the current four-way interaction). Looking across all four panels, the relationship between the Medium and High Trait-Anxious Groups appears quite consistent across both Paradigm and Task. Indeed, as mentioned earlier, Figure 8.18a shows all effects, bar Trial type, to be quite consistent in the Alternating-Runs Paradigm. Here, mean P3 amplitudes for the Low and Medium Trait-Anxious Groups are considerably higher than those for the High Trait-Anxious Group, with the Repressor Group intermediating. Using the stable amplitudes produced by the Medium and High Trait-Anxious Groups as a reference, a reduction in P3 amplitude is evident for the Low Trait-Anxiety and Repressor Groups when comparing the means from the Alternating-Runs Paradigm in Figure 8.18a with those from the Task-Cueing Paradigm in Figure 8.18b. This reduction in P3 amplitude from the Low Trait-Anxiety and

Repressor Groups is consistent across both Task and Trial type, with the exception of the Repressor Group when switching to the Global Task.

The main effect for Trial was significant, $F(1,53)=36.70$, MSE=5.46, $p<.001$, $\eta^2=.397$. As hypothesised, P3 amplitude in response to Switch trials ($M=12.19$, $SEM=0.63$) was indeed found to be lower than that in response to Repeat trials ($M=13.53$, $SEM=0.66$). The strength of this effect provides support for the validity of the methodology relative to previous findings.

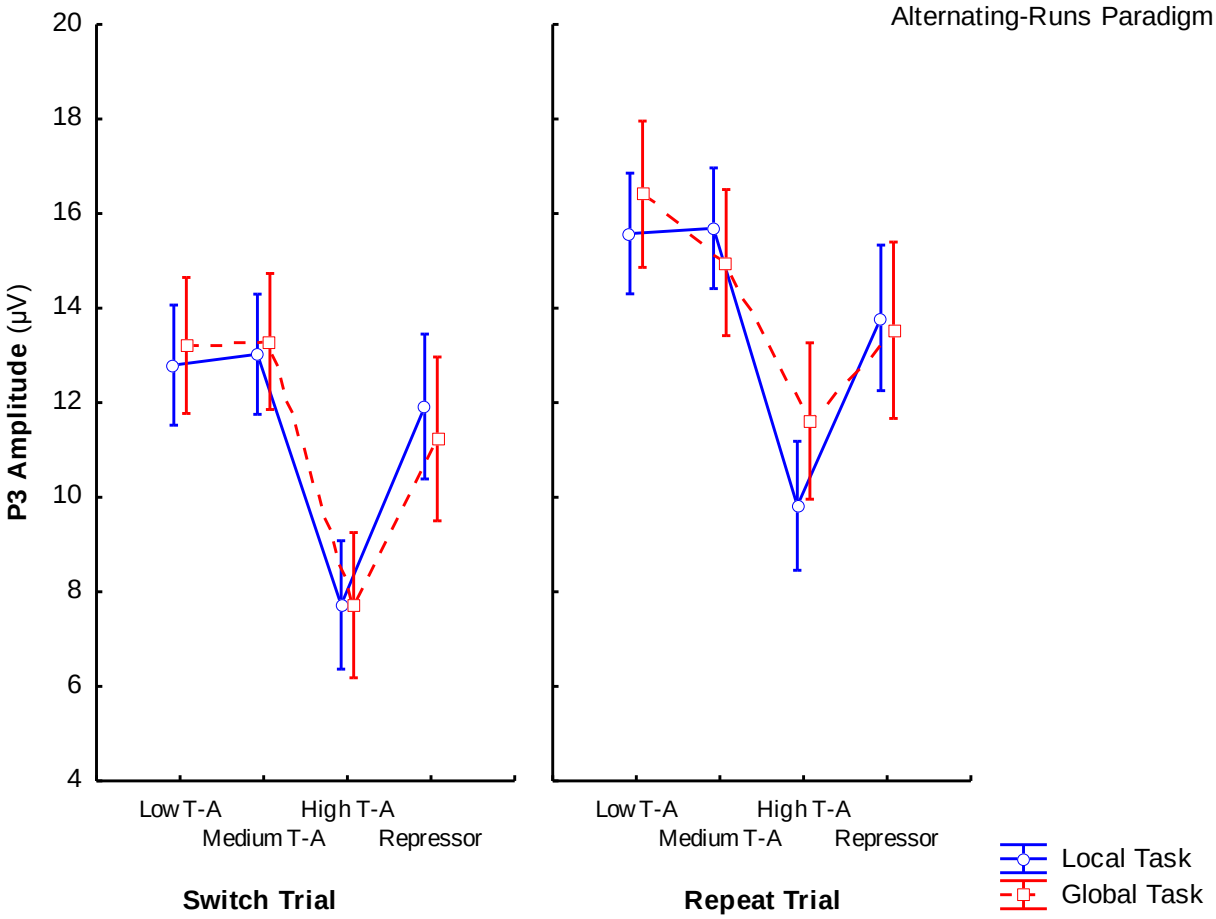

Figure 8.18a. P3 amplitude for each of the four groups, for both trials, on both tasks, within the alternating-runs paradigm (vertical bars denote SEM).

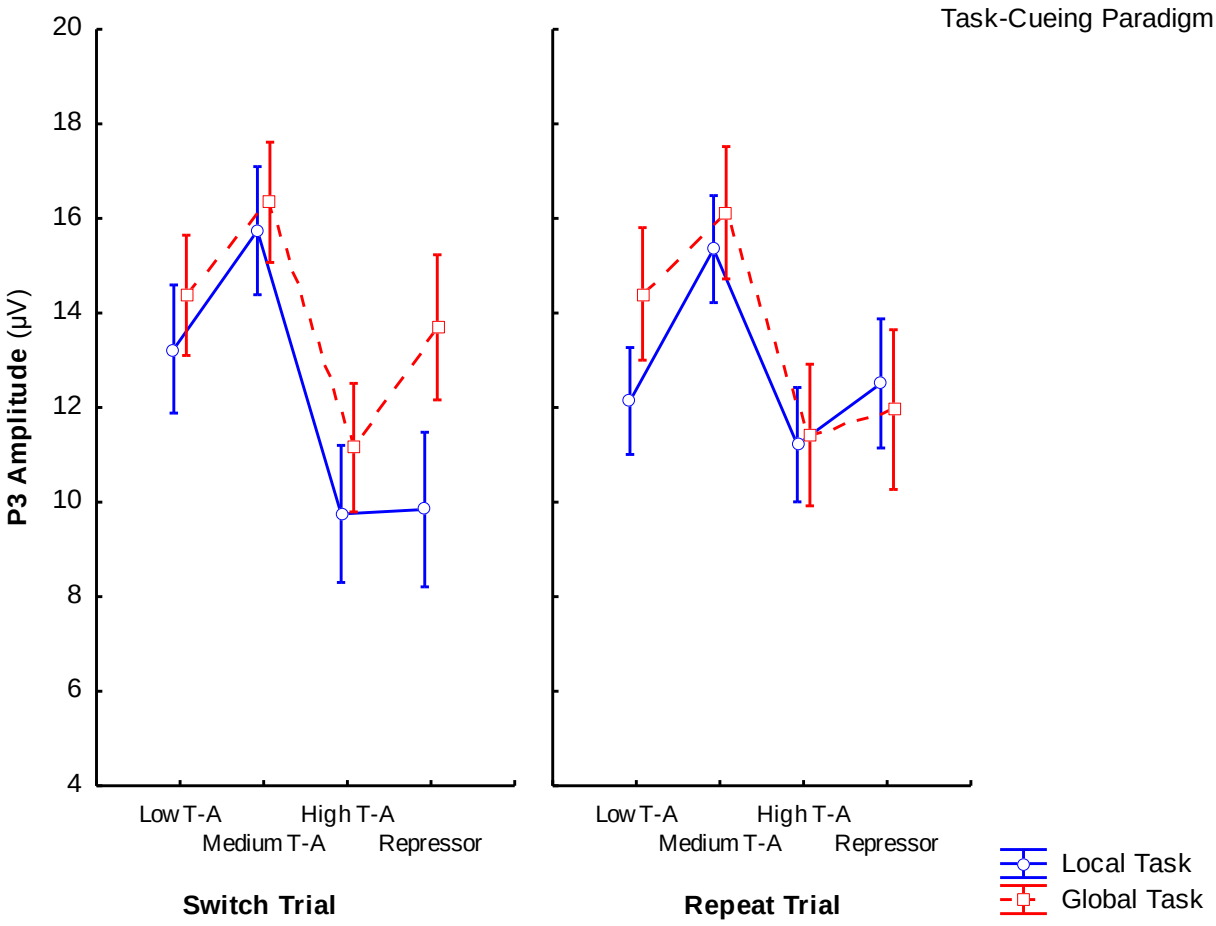

Figure 8.18b. P3 amplitude for each of the four groups, for both trials, on both tasks, within the task-cueing paradigm (vertical bars denote SEM).

P3 Latency

The Group x Paradigm x Task x Trial mixed ANOVA at Pz showed the main effect for Group not to be significant, $F(3,53)=2.04$, MSE=35050, $p=.120$. Nor was Group involved in any significant interactions.

Switch-Cueing Effects

Raw data were participants' EEG to switching cues. Each participant's peak amplitude (μV) and latency (ms) for the N1, P2, N2 and P3 components were initially subjected to 4 [Group: Low-Anxious, Medium-Anxious, High-Anxious, Repressor] x 2

(Task: Local, Global) mixed ANOVA at selected Sagittal sites, according to the dictates of the respective hypotheses and the topographical distributions of each component, as discussed earlier. Hence, P3 was analysed only at Pz, and N2 only at Fz; whereas P2 and N1 were both analysed at each of Fz, Cz and Pz. Huynh-Feldt correction to degrees of freedom was applied where necessary. Tukey's HSD test was used to evaluate the significance of differences underlying main effects and interactions between factors where necessary. Effects were considered statistically significant at, or below, p=.05.

N1 Amplitude

The Group x Task x Sagittal mixed ANOVA for N1 amplitude indicated the main effect for Group did not reach significance, $F(3,53)=1.96$, MSE=14.55, p=.132. Nor was Group found to interact significantly with the factors of Task or Sagittal.

N1 Latency

The Group x Task x Sagittal mixed ANOVA for N1 Latency showed the main effect for Group not to be significant, $F(3,53)=0.29$, MSE=318.00, p=.831. Further, Group did not interact significantly with Task or Sagittal.

P2 Amplitude

The Group x Task x Sagittal mixed ANOVA for P2 amplitude indicated the main effect for Group did not reach significance, $F(3,53)=1.41$, MSE=59.33, p=.251. Group was not found to interact significantly with either Task or Sagittal.

P2 Latency

The Group x Task mixed ANOVA for P2 Latency revealed the main effect for Group to be significant, $F(3,53)=5.20$, MSE=1654.00, p=.016, η^2=.177. Figure 8.23 shows that the earliest P2 was produced by the High Trait-Anxiety Group (M=182.69, SEM=5.43), followed closely by the Repressor Group (M=186.11, SEM=6.13), with P2 produced by the Medium (M=198.94, SEM=5.08) and Low Trait-Anxiety (M=204.70, SEM=5.08) groups peaking much later, in relative terms. Post-hoc testing indicated that the High Trait-Anxiety group produced significantly earlier P2 than the Low (p=.007)

and Medium (p=.024) Trait-Anxiety groups, whereas the Repressor group only trended toward earlier P2 in comparison to the Low Trait-Anxiety group (p=.088). Hence, the Low and Medium Trait-Anxiety Groups produced later P2 than the High Trait-Anxiety and Repressor Groups. No other effects of interest were found to approach or achieve significance.

N2 Amplitude

The Group x Task mixed ANOVA for N2 amplitude to switch cues at Fz showed the main effect for Group to be significant, $F(3,53)=3.73$, MSE=40.42, p=.017, η^2=.174. The Repressor Group produced the greatest N2 amplitude (M=-6.03, SEM=1.36). Interestingly, the next greatest N2 amplitude was produced by the Medium Trait-Anxiety Group (M=-4.21, SEM=1.12), followed by the High Trait-Anxiety Group (M=-1.23, SEM=1.20), with the Low Trait-Anxiety Group slightly lower, again (M=-1.10, SEM=1.12). Whereas the post-hoc analysis indicated that N2 produced by the Repressor Group was significantly larger than that by the Low Trait-Anxiety Group (p=.035), and bordered on significance with the High Trait-Anxiety Group (p=.051), it was not significantly different to that produced by the Medium Trait-Anxiety Group. The Group x Task interaction did not reach significance.

N2 Latency

The Group x Task mixed ANOVA for N2 latency at Fz indicated the main effect for Group to be non-significant, $F(3,53)=0.57$, MSE=1136, p=.635. The Group x Task interaction was also found not to be significant.

P3 Amplitude

The Group x Task mixed ANOVA for P3 amplitude at Pz indicated a non-significant main effect for Group, $F(3,53)=1.42$, MSE=55.74, p=.247, and Task $F(1,53)=1.64$; with the Group x Task interaction also found not to be significant.

P3 Latency

The Group x Task mixed ANOVA for P3 latency at Pz showed the main effect for Group not to be significant, $F(3,53)=1.59$, MSE=3326.00, $p=.204$. The Group x Task interaction was also non-significant.

Discussion

The aim of the present study was to investigate the effect of latent trait-anxiety on attentional resource allocation processes employed in task-switching. Participants classified as either: low, medium, or high trait-anxious; or repressors, performed neutrally-valenced switching tasks comprising bivalent stimuli. The influence of bottom-up and top-down factors were investigated through analyses of data from two task-switching paradigms; those being task-cueing and alternating-runs. In addition to measures of response latency and accuracy, ERPs were employed to provide metrics of the timing and intensity of neural activity associated with cognitive resource allocation during event processing. The results of the present study indicated many effects of interest as statistically significant. Discussion of each of these is impracticable. As such, discussion is restricted to those results considered central to the current aims and hypotheses.

As mentioned in the introductory section of the current chapter, the bivalent task stimuli used in the present study were configured in arrays that could be considered local-global in nature. Whereas local-global and emotional processing are both hemisphere-dominant processes, the focus of the present thesis was on emotion-neutral processing. Further, the number-numerosity task used in the current study is not the established paradigm for research on local-global processing. Hence, laterality aspects of local-global processing were not investigated.

Performance Effects

Response Latency

The hypothesis that response latencies would be significantly longer to switch trials than repetition trials was strongly supported by a main effect of exceptional magnitude (η^2=.756). This is consistent with the classic, robust, switch-cost effect of increased latency (see Gajewski & Falkenstein, 2011), and demonstrates the success of the task-switching manipulation in both the alternating-runs and task-cueing paradigms.

Further, it was suggested that the combination of extra processing time and interference of task-set inertia afforded by the task-switching cue may result in shorter response latencies within the task-cueing paradigm, compared to the alternating-runs paradigm. The paradigm x trial interaction provided partial support for this. Whereas responses to switch trials were later within the alternating-runs paradigm, responses to repeat trials showed no difference in response latency across the paradigms.

As the experimental stimuli employed in the present study were ostensibly non-valent, there was no expectation that response latency would be sensitive to differential processing between groups. Nevertheless, it was suggested that, due to the propensity for high trait-anxious individuals to show retarded disengagement this group would be the most likely to produce longer response latencies, particularly on switch trials. The results did not support this. Whereas the main effect for group did not reach significance, group was found to interact significantly with paradigm; though this interaction showed only a pattern of mild effects that were not of interest to the present study. There were no significant local-global effects.

Summary

The task-switching methodology employed in the current study successfully effected a strong switch-cost for response latency. The moderation of this switch-cost within the task-cueing paradigm was most likely due to task-set reconfiguration facilitation effected by the extra processing time. Nevertheless, the novel stimulus attributes of the cue may have effected interference, which would assist with degradation of task-set inertia.

Response Accuracy

Given that increased error rate is not nearly as robust a switch-cost as increased response latency, effects for response accuracy were not expected to reach significance. Nevertheless, it was predicted that any differences in response accuracy would manifest according to the expectations specified for response latency. The analyses indicated several significant effects. Trial type was found to interact significantly with paradigm with associated post-hoc tests showing a significant switch-cost effect, whereby response accuracy was greater for repeat trials than switch trials. Further, again in line with expectations, this switch-cost was shown to be greater in the alternating-runs paradigm than the task-cueing paradigm. As was the case with the corresponding interaction for response latency, accruacy on repeat trails was not found to differ between paradigms. These results indicate that overall, and as expected, participants found switch trials more difficult than repeat trials – the switch cost effect. Further, the switch-cost was more prominent in the alternating-runs paradigm. This may be attributed to the increased preparation time, and prospective interference of task-set inertia afforded in the task-cueing paradigm.

Paradigm was also found to interact significantly with group and task. Post-hoc analysis showed only one significant relevant accuracy effect. This involved repressors performing the global task with greater accuracy within the task-cueing paradigm than within the alternating-runs paradigm. This effect is surprising. Whereas better performance with the task-cueing paradigm is as would be expected – due to the greater preparation time and prospective interference of task-set inertia, afforded by the switch-cue – that this effect should occur when performing the global task, rather the local task, is curious. Inspection of the graph of this interaction in Figure 8.3 shows the low, medium and high trait-anxiety performing with lower accuracy on the local task within the alternating-runs paradigm. This may be explained by the combination of shorter preparation time and interference caused by the global precedence effect. Unlike the other three groups, the repressor group does not appear to be affected. Retuning to the global task, whereas the global precedence effect appears to have facilitated accuracy for the low, medium and high trait-anxiety groups, it appears to have had a detrimental effect for the repressor group. Further, the other three groups showed no change in

accuracy between the local and global tasks within the task-cueing paradigm – perhaps representing a within-groups ceiling effect. This was not the case for the repressor group, who showed a somewhat marked improvement in accuracy. Indeed, this represented the highest accuracy of any group in the context of the interaction, whereas the performance of this group on the global task within the same paradigm represented the lowest accuracy of any group.

This finding is not easily accounted for. It appears that when processing the global task, the repressor group were singularly adversely affected by the absence of task-cueing, and assisted by the presence of task-cueing. Whereas this effect does not accord strongly with existing theory, it may be considered that repressors possess a bias toward compartmentalised processing of information. That is, greater processing of discrete elements. If this is the case, then it would not be unexpected that a bias toward local stimuli would more readily persist under conditions of low interference, such as with the alternating-runs paradigm. Further, if repressors do indeed possess a greater general flexibility of attentional control, then it may be considered that the more global process of reading the cue instruction could both interrupt local processing and prime global processing. If this is the case then it would not be unexpected that the repressor group would show improved performance on the global task in the task-cueing paradigm, along with reduced performance on the local task.

Summary

The effect of increased error rate on switch trials, compared to repeat trials, is not as robust as that of increases in response latency. Given this, the presence of similar switch-cost effects to those found for response latency provides unequivocal confirmation of the validity of the present task-switching methodology. This includes the moderation of switch-costs within the task-cueing paradigm, which was attributed to the increased preparation time, and prospective interference of task-set inertia afforded by the novel stimulus attributes of the cue.

As anticipated, there were no overall differences between the groups on response accuracy. There was, however, an effect found whereby the repressor group performed the global task with greater accuracy within the task-cueing paradigm than the within the

alternating-runs paradigm. In accounting for this, it was suggested that repressors may possess a bias toward compartmentalised processing of information, which enhanced attention to discrete elements of task stimuli. In addition, it was suggested that this bias may have been offset in the task-cueing paradigm through the priming of global processing effected by the reading of the cue instruction. Finally, it was suggested that should this be the case, it would be consistent with the notion that repressors possess a greater general flexibility of attentional control that is sensitive to top-down input.

ERP Effects

Overall, the grand mean waveforms showed typical topographical distributions for each of the components of interest. The N1 and P2 components both showed fronto-central maximas at the midline. The N2 and P3 components were clearly maximal at Fz and Pz, respectively.

Task-Execution Effects

N1 Amplitude

The dominant effect for N1 amplitude was the significant group x paradigm interaction. In the absence of significant post-hoc tests, overall amplitudes appeared to be around 0.5 μV greater at Fz than Cz. It was at Cz that the likely driver of the interaction occurred, which involved the high trait-anxiety group producing somewhat lower N1 amplitude within the task-cueing paradigm relative to the alternating-runs paradigm. Perhaps this peculiarity was responsible for the main effect of group only trending toward significance (p=.076). Here, N1 amplitude appeared to increase as a function of latent trait-anxiety, from the low, through the medium and high trait-anxiety groups, up to repressors. This pattern for increased N1 amplitude matches expectations of the relative behaviour of these groups with respect to arousal, vigilance, and motivation for early stimulus discrimination and information gain for downstream processing (Kieffaber & Hetrick, 2005; Kok, 1997, 2001; Mangun & Hillyard, 1990).

N1 Latency

For N1 latency, the main effect for group did not approach significance. Group was, however, involved in two higher-order interactions. The significant group x paradigm x trial interaction showed the earliest and latest N1 peaks were produced by the repressor group when performing switch trials. Within the task-cueing paradigm, the repressor group conducted N1-related processing on switch trials relatively quickly. Within the alternating-runs paradigm, however, the repressor group took much longer to conduct the processing indexed by N1, in relative terms. This disparity in processing time was markedly reduced when the repressor group performed repeat trials.

Whereas these effects were not supported by significant post-hoc results, this pattern is consistent with what may be expected in terms of early processing strategies by repressors. That is, longer processing times associated with the relative novelty of the switch trial in the absence of the extra time and surety provided by the cue. Alternatively, when this extra time and surety were provided, repressors used these to achieve superior processing speed. These effects appear to have been modified by the presumed reduction in processing demands associated with task-set inertia and task-set reconfiguration when performing repeat trials. These effects are consistent with the notion that repressors may possess superior attentional flexibility, relative to the other groups.

Group and paradigm were also found to interact significantly with task. Whereas no relevant post-hoc effects reached significance, the graph of this interaction showed quite some similarity to that for the group x paradigm x trial interaction, discussed directly above. This was particularly so in the case of the repressor group, for which the similarities across the interactions were striking. As with the previous interaction, the absolute longest N1 latency was produced by repressors within the alternating-runs paradigm, though when performing the local task (cf. switch trials in the previous interaction). In addition, the latency of N1 produced by the repressor group when performing the local task within the task-cueing paradigm was very nearly the absolute shortest – again, markedly similar to the previous interaction. In addition, this disparity in processing time across the paradigms by repressors was considerably reduced when performing the global task (cf. repeat trials in the previous interaction).

The close similarity of effects between these two interactions may be understandable in terms of correspondence of the relative processing demands of the levels within the inconsistent factors. That is, switch trials may be considered more processing intensive than repeat trials; and the local task more demanding than the global task. Hence, in relative terms, the processing demands of switch trials may correspond to those of the local task, whereas the processing demands of repeat trials may correspond to those of the global task.

Returning to the effects for repressors in the group x paradigm x task interaction, the relatively late peak when performing the local task within the alternating-runs paradigm indicates that repressors took longer to perform the processes indexed by N1. As discussed in Chapter 4, these processes are considered to involve early selection for further processing. Whereas N1 is initially driven by incoming information it has been shown to be strongly influenced by higher order operations. Of particular relevance to the present study are the findings linking N1 to visual discrimination processes (e.g., Mangun & Hillyard, 1991; Vogel & Luck, 2000; Wascher et al., 2009). These have led to the proposal that N1 may indeed reflect the initial functional integration of multiple sources of information presumed to occur in early selective attention (Wascher et al., 2009).

Hence, in the alternating-runs paradigm, the later N1 produced by repressors when performing the local task may indicate a slower resolution of the global precedence effect. This suggestion is supported by the finding of much earlier N1 by repressors to the local task within the alternating-runs paradigm. Here, the prospective interference of task-set inertia and/or extra preparation time afforded by the switching cue appears to have effected sufficient interference to task-set inertia, and/or facilitated task-set reconfiguration to allow repressors to process the local task in similar time to the other three groups. The question remains, however, as to why the repressor group may be so sensitive to the global precedence effect.

Revisiting the discussion of the corresponding significant interaction for response accuracy may assist in understanding the N1 latency effects for repressors. First, it is helpful to review the graphs of the significant group x paradigm x task interaction for both response accuracy (Figure 8.3) and N1 latency (Figure 8.12). Comparison of these

shows an inversion of effects for the repressor group. For response accuracy, divergence between paradigms occurred on the global task, with negligible difference to the local task; whereas this was the opposite for N1 latency.

The superior response accuracy by the repressor group, relative to the other three groups, within the alternating-runs paradigms when performing the local task was in stark contrast to both the relative and absolute performance of this group on the global task. This marked decline in response accuracy for the global task within the alternating-runs paradigm was contrasted by an equally large improvement in response accuracy within the task-cueing paradigm. It was suggested that this may reflect a characteristic bias whereby repressors engage in more compartmentalised processing, resulting in enhanced attention to the discrete stimuli. This account would also explain the facilitated performance on the local task, and impaired performance on the global task.

It was further suggested that the prospective interference of task-set inertia, and potential global priming, afforded by the switch-cue may have interacted with a greater attentional flexibility possessed by repressors, to effect a marked facilitation of performance on the global task. Indeed, if any global priming was facilitated by the reading of the switch-cue, the corresponding interference may account for the relative decrement in response accuracy observed for the local task. To summarise, in the case of response accuracy, it was suggested that repressors may posses a characteristic bias for elemental processing which facilitated performance in local task, but impaired performance in the global task. This was, however, inversely modified by the task-cue. It was suggested that reading the cue may have primed global processing, thereby improving performance on the global task, and impairing it on the local task.

As mentioned earlier, this account for the effects shown by the repressor group on response accuracy may assist in understanding the N1 latency effects for repressors. For instance, without the context of the response latency effects, the later N1 by repressors within the alternating-runs paradigm to the local task, compared to the global task, may be simply attributed to a global-precedence effect. Such a simple explanation is not consistent with the observation of much higher accuracy to the local task, compared to the global task, however. Whereas resolution of task-set inertia is likely to have contributed to processing time, the simple resolution of interference would be

considered to facilitate such marked increase in response accuracy when compared to the same condition in the global task.

One possible explanation is that of preferential processing of local elements by repressors. Should repressors posses a characteristic bias for attention to discrete stimuli, then the enhanced processing may take more time and/or resources. Further, should this processing co-occur with the resolution of the global precedence bias, later N1 would be expected. In addition, such co-occurring processes are likely to increase demand on attentional resources. This may have been reflected in the trending main effect whereby repressors showed the largest N1 amplitude of all four groups.

Regarding the task-cueing paradigm, the earlier N1 by repressors to the local task may reflect the ability of the cue to facilitate task-set reconfiguration and/or interruption of task-set inertia. Given the lack of corresponding response accuracy in this condition, however, the former may be preferred over the latter. It may have been that strong top-down priming allowed sufficient resolution to activate information passage prior to sufficient resolution of the global attributes. The resultant passage of global information would likely compromise the clarity of information as it passes through the processing chain. Hence, the cue did not appear to facilitate the performance of the repressor group on the local task.

Aspects of the account provided directly above may also explain the combination of effects whereby within the alternating-runs paradigm repressors showed much earlier N1 on the global task, along with markedly reduced response accuracy, compared to the local task. Whereas earlier N1 would be expected due to the global precedence effect, the marked reduction in response accuracy does not accord. It is not unlikely that due to global precedence, threshold for information transmission may have been reached prior to the resolution of local elements, which may attract enhanced processing in repressors. As was the case for the previous effect, this contamination may have compromised response accuracy.

There is one final aspect of the significant group x paradigm x task interaction for N1 latency that requires explanation. This involves the later N1 produced by the repressor group on the global task compared to the local task, within the task-cueing paradigm. This apparent difference is likely an artefact of what may be considered as a

premature N1 on the local task. This position is supported by the corresponding response accuracy effects, which showed relatively low performance on the local task, compared to relatively high performance on the global task.

In summary, the results of the group x paradigm x task interaction indicated that N1-related processing by repressors was differentially affected by the task-cue and local-global interference. Toward understanding these effects, convergent evidence from the corresponding interaction for response accuracy was discussed, along with the trend toward a significant main effect for group for N1 amplitude. Together, these results suggest that repressors may possess a characteristic bias toward enhanced attention to stimulus elements. Further, the pattern of results for repressors led to the suggestion that switch-cues, in addition to providing increased preparation time, and prospective interference of task-set inertia, may possibly effect some priming of global processing. It was suggested that these effects, in particular combination, may have led to premature passage of irresolute information; subsequently compromising the performance accuracy of the repressor group.

Summary of N1 Latency Findings

Whereas the main effect for group did not approach significance for N1 latency, group was involved in two higher-order interactions involving paradigm. The group x paradigm x trial interaction showed the earliest and latest N1 peaks were produced by the repressor group when performing switch trials, within the task-cueing and alternating-runs paradigms, respectively. Whereas these effects were not supported by significant post-hoc results, the pattern is consistent with what may be expected in terms of early processing strategies by repressors. That is, longer processing times associated with the relative novelty of the switch trial in the absence of the extra time and surety provided by the cue. Alternatively, when this extra time and surety were provided, repressors used these to achieve superior processing speed. Taken together with dissipation of this difference for the repeat trials, these effects are consistent with the notion that repressors may possess superior attentional flexibility, relative to the other groups.

The necessarily convoluted discussion of the group x paradigm x task interaction for N1 latency was also focussed on effects apparent for the repressor group, and also not supported by post-hoc tests. These effects involved the repressor group being differentially affected by the task-cue and local-global interference. In accounting for the observed pattern of results, a prospect raised in the discussion of the corresponding effect for response accuracy was drawn upon. It was proposed that repressors may possess a bias toward enhanced attention to discrete elements; and that such a bias may reflect a propensity for compartmentalised processing of information that might be considered characteristic of repressors.

P2 Amplitude

The anticipated attenuation of P2 amplitude to switch trials, relative to repeat trials, did not occur. This expectation was based on the effect of attenuated P2 to switch trials reported by Kieffaber and Hetrick (2005). Two methodological factors may have contributed to the lack of replication of this effect in the current study. First, whereas Kieffaber and Hetrick used similar SOA (1200ms) to that employed in the present study, their task comprised size and shape discrimination of a pair of simple geometric objects. In addition, Kieffaber and Hetrick presented task-cues verbally, and provided visual performance feedback. Together, these differences may constitute sufficient divergence in the qualitative demands of the experimental conditions to account for inconsistent ERP findings. Second, Kieffaber and Hetrick took what they termed a "non-conventional" approach to data analysis. This involved MANOVA on scores extracted from spatio-temporal principal components analysis decomposition. The combination of these differences in methodology may be considered to undermine the comparability of the results of the current study to those reported by Kieffaber and Hetrick.

The interpretation offered by Kieffaber and Hetrick (2005) for the attenuated P2 to switch trials gave rise to two further hypotheses. According to Kieffaber and Hetrick, P2 in task-switching paradigms provides an index of the strength of stimulus-response association, in that it reflects stimulus-dependent processes such as the retrieval of stimulus-response associations activated by salient properties of target stimuli. It was proposed that, should repressors possess superior attentional flexibility, then this would

likely facilitate stimulus-response association. As such, it was anticipated that the repressor group would produce the largest P2 amplitude of all four groups, to both switch and repeat trials.

This was not supported by the results. The significant main effect for group indicated that, rather than producing the largest P2 amplitude, the repressor group produced the lowest of all four groups. Whereas post-hoc tests confirmed this difference relative to the medium trait-anxiety group (p=.020), this only approached significance for the low-trait anxiety group (p=.105), and was not significant relative to the high trait-anxiety group. Accounting for this effect is particularly difficult given that remarkably little is known about the underlying neurological or functional correlates of P2 (Crowley & Colrain, 2004; Freunberger et al., 2007). As such, the present effect for low P2 amplitude may be somewhat understood with reference to the N1 produced by the other three groups.

As expected, P2 amplitude for the high trait-anxiety group was, in relative terms, lower than those for the medium and low trait-anxiety groups; however, not significantly so. This pattern is consistent with the lack of stimulus-response association presumed to result from characteristic retarded attentional disengagement by high trait-anxious individuals (Bar-Haim et al., 2007; Derakshan et al., 2009; Derryberry & Reed, 2002). Such an explanation would also fit with the broader ideas concerning the functional correlates of P2, presented in Chapter 4, as indexing facilitation of feature detection and stimulus discrimination, including interference reconciliation, at early stages of encoding.

The account of P2 as reflecting the facilitation of feature detection and stimulus discrimination, along with interference reconciliation, avails a credible explanation for the low P2 amplitude for the repressor group. If repressors do posses a bias toward enhanced attention to discrete elements, then this would not only account for the lack of reconciliation relative to the other groups; particularly the low and medium trait anxiety groups.

P2 Latency

None of the relevant effects for P2 latency achieved, or approached significance; nor were these expected to.

N2 Amplitude

The main effect for Trial type was not found to be significant. Consequently, the hypothesised effect for greater N2 amplitude to switch trials relative to repeat trials was not supported. The prediction of enhanced N2 to switch trials was based on the findings of Gajewski and Falkenstein (2011) and Gajewski et al. (2010). Both of these studies, however, employed a combined go/no-go task-switching paradigm.

Whereas go and no-go N2 have been reliably differentiated (e.g., Lavric, Pizzagalli, & Forstmeier, 2004), both have been found to be larger when the frequency of go trials increased from 50% to 80% (e.g., Donkers & van Boxtel, 2004). Hence, the 75% frequency of go trials presented in the experiments reported by Gajewski and Falkenstein (2011) and Gajewski et al. (2010) is likely to have inflated the switch-N2. In the absence of other reported findings of enhanced switch-N2, this may be considered to account for the absence of enhanced N2 to switch trials in the present study.

The significant main effect for group provided initial support for the hypothesis that N2 amplitude produced by the repressor group would be greater than that produced by each of the other three groups. Post-hoc tests, however, confirmed this only in relation to the low trait-anxiety group. Indeed, no other differences for the main effect were found to be significant. The expectation that the repressor group would show the largest N2 amplitude was based on the results from the Stroop experiment, presented in Chapter 7, where the repressor group produced the largest N2 amplitudes to interference stimuli. On the basis of that finding, it was suggested that repressors appeared more susceptible to interference from task-irrelevant information than each of the other groups, as initially mooted.

The proposal that N2 amplitude in the current study would show similar reduction as a function of latent anxiety, as found for Stroop interference in the previous study, was not supported. The low trait-anxiety group did show the least amplitude, however, N2 produced by the high trait-anxiety group was slightly lower than that produced by the

medium trait-anxiety group. Again, post-hoc tests showed none of these differences to be significant.

Summary of N2 Amplitude Effects

As discussed earlier in the present chapter, and in Chapter 4, anterior N2 has been associated with conflict detection during response selection (see Yeung & Cohen, 2006), and is particularly prominent in situations involving coactive incompatible response tendencies (see Folstein & Van Petten, 2008 for a review). Hence, as expected, a prominent anterior N2 was elicited by both switch and repeat trials. The absence of the hypothesised effect for enhanced N2 to switch trials, relative to repeat trials, was explainable by the qualitative divergence between the current switch task, and the combined go/no-go switch task employed by Gajewski and Falkenstein (2011) and Gajewski et al. (2010). Indeed, the absence of enhanced switch-N2 reported in other ERP studies was considered to support the lack of such a finding in the present results.

Whereas the group effects were not completely consistent with the vigilance-avoidance perspective, the repressor group appeared to produce the largest N2 amplitude of all four groups, and the low trait-anxiety the smallest. Whereas this difference was significant, those relative to the intermediating medium and high trait-anxiety groups were not. This finding adds collateral evidence to the proposal emanating from the findings of the Stroop experiment presented in the previous chapter; repressors appear to remain open to interference from unwanted information at the stage of conflict monitoring associated with response selection.

N2 Latency

There were no predictions made for N2 latency; however, the profile of the significant group x paradigm x task interaction was of some interest. This showed a clear tendency for N2 to peak latest for the high trait-anxiety group, with those for the other three groups relatively similar. None of these effects were confirmed by post-hoc analysis, however. Nevertheless, taken together with the results for N2 amplitude, the between-group processing profile on N2 may represent the beginnings of divergence from the pattern whereby effects have tended to correspond with latent anxiety.

P3 Amplitude

The strong expectation for attenuated P3 to switch trials relative to repeat trials was supported by the significant main effect for trial. The strength of this effect (η^2=.397) provides potent support for the validity of the methodology in relation to this robust effect (e.g., Barceló et al., 2006; Gajewski & Falkenstein, 2011; amongst others mentioned earlier). As discussed earlier, whereas several ideas have been posited for the attenuated P3 in switch trials (e.g., Kieffaber & Hetrick, 2005; Verleger et al., 2005), the strongest are consistent with that proposed by Lorist et al. These authors argue that switch trails are more processing intensive than repetition trials, resulting in fewer resources being available for the accomplishment of other P3-related activities, and hence, reduced P3 (as per Kok, 2001; Wickens et al., 1983).

The association between high trait-anxiety and retarded attentional disengagement led to the expectation that any group differences in P3 would be in the direction of lower P3 amplitude for the high trait-anxiety group compared to each of the other three groups, particularly on switch trials. Partial support for this was found within the significant main effect for group, whereby P3 was shown to be lowest for the high trait-anxiety group, overall. This was, however, clearly modified by higher order interactions. Prior to discussing these, however, it is worth recalling that the expectation P3 amplitude for the repressor group would not differ to the medium and high trait-anxiety groups was formed according to the vigilance-avoidance model, which posits that repressors can effect attentional avoidance of unwanted information at later stages of cognitive processing (Calvo & Eysenck, 2000; Derakshan et al., 2007).

The significant group x paradigm x task x trial interaction is represented across Figure 8.18a and Figure 8.18b. Whereas none of the relevant effects were found to be significant on post-hoc testing, examination of the figures may provide useful information on the attentional processing characteristics of the groups of interest. At the outset, it is helpful to observe that P3 for both the medium and high trait anxiety groups remain quite stable throughout the interaction. Indeed, the difference in P3 amplitude between these groups (which was the only effect to reach significance on post-hoc tests of the significant main effect for group) was relatively consistent across conditions. The

most notable exception to the stability of P3 for the medium and high trait-anxiety groups was the attenuation to switch trials within the alternating-runs paradigm, which was shown by all four groups. Given that the robust nature of switch-attenuated P3 (discussed earlier), it may be considered that the medium and high trait anxiety groups provided a stable reference against which to compare P3 produced by the low trait-anxiety and repressor groups.

The medium and high trait-anxiety groups showed little variation in their respective P3 amplitude to repeat trials across the paradigms, suggesting that task-cueing did not affect the way these groups processed repeat trials. This was not the case for the low trait-anxiety and repressor groups, however. Both of these groups showed a similar, appreciable reduction in P3 amplitude (approximately 2.0 μV). According to the vigilance-avoidance model (Derakshan et al., 2007), it would not be unexpected that the low trait-anxiety and repressor groups may show similar patterns at later-stage processing. These groups also showed a somewhat similar effect on switch trials within the task-cueing paradigm.

Given the increased preparation time and prospective interference of task-set inertia afforded within the task-cueing paradigm, processing associated with task-set reconfiguration at this relatively late stage of processing may be considered to be less demanding relative to the alternating-runs paradigm. In such a situation, the low trait-anxiety group may be considered most likely to reduce effort through passive withdrawal of processing resources. This proposal is based on the ERP findings of Pailing and Segalowitz (2004), who investigated the relationship between personality and motivation. These authors reported that individuals rated as low on neuroticism showed more incentive-related enhancement of error-related negativity than individuals rated as high on conscientiousness. As discussed in Chapter 2, the constructs of trait-anxiety and Neuroticism are typically found to be highly correlated (Eysenck, 2004). Hence, individuals rated as low in neuroticism may be considered similar to the low trait-anxiety group of the present study. As such, it may be the case that the low trait-anxiety group possesses somewhat lower intrinsic motivation when performing experimental tasks that are not incentive-based. In contrast, it may be suggested that, of each of the four groups in the present study, the medium trait-anxiety group is likely to

best fit the construct of conscientiousness. If this was the case, their associated intrinsic motivation would account for the apparent maintenance of effort evidenced by enhanced P3 amplitude in the task-cueing paradigm for this group.

The passive withdrawal of attentional resources by the low trait-anxiety group during the less demanding task-cueing paradigm may assist the understanding of similar P3 attenuation by the repressor group. According to Vigilance-Avoidance Theory (Derakshan et al., 2007) the repressor group may be argued as functioning similarly to the low trait-anxiety group at this relatively late stage. Whereas this account may be reasonably applied to the repressor group for processing of repeat trials, it does not appear to hold for switch trials.

During the task-cueing paradigm, the repressor group showed marked difference in P3 to switch trials, whereby amplitude on the local task was distinctly lower than on the global task. Indeed, this was the only condition in which the repressor group showed any disparity in processing between local and global tasks. Given this, the effect was attributed to the prospective global priming afforded by the cue. As detailed in the discussion of response accuracy and N1 latency data, the repressor group appear to be differentially affected by the switch-cue on local-global processing. In relation to the present effect, it may be that the switch-cue primed global processing. If this was the case, then the resultant facilitation for the global task would explain the relatively large P3, whereas the interference effected for the local task would explain the attenuated P3. Such susceptibility to interference at this late stage by the repressor group may account for the pattern of group effects.

According to Vigilance-Avoidance Theory (Derakshan et al., 2007), repressors are considered to engage in enhanced early processing of events. At later stages, however, repressors are considered capable of superior inhibition of attention toward unwanted information. Prior to the P3, the group effects for the N2, P2 and N1 components all showed a pattern whereby amplitudes increased (for N2 and N1), or decreased (for P2) as a function of latent anxiety. Notwithstanding some of the effects in the task-cueing paradigm, the group effects for P3, however, show a pattern whereby repressors appeared less affected by the demands on processing resources observable as a function of latent anxiety on the earlier components. This is very well represented in the profile

of group effects within alternating-runs paradigm presented in Figure 8.18a. These effects are consistent with, and provide partial support for a late-stage processing advantage for repressors – at least relative to their high trait-anxious counterparts.

Summary of P3 Amplitude Effects

As discussed in Chapter 4, considered to be the first wholly endogenous ERP component (Donchin, 1981; Johnson, 1986), P3 reflects processing involved in the final stages of higher-order selective attention. More specifically, it is held to be related to the evaluation and categorisation of task-relevant stimulus events (Donchin, 1981; Hillyard & Kutas, 1983). As such, P3 is commonly considered to provide a useful index of the attentional resource activation involved in decision making processes (Donchin, 1981; Hillyard & Kutas, 1983; Johnson, 1986; Kok, 1997, 2001; Polich, 2007; Verleger et al., 2005).

As expected, the very strong effect for attenuated P3 to switch trials relative to repeat trials supported the validity of the present methodology. As anticipated, the significant main effect showed the lowest overall P3 amplitude was produced by the low high trait-anxiety group; however this was confirmed as significant only in relation to the medium trait-anxiety group. Further, this main effect was modified by the significant group x paradigm x task x trial interaction. Whereas post-hoc tests did not confirm any of the relevant effects, this complex interaction showed strong patterns of interest.

First, the pattern of P3 amplitude for the medium and high trait-anxiety groups was very stable across the interaction. It was suggested that the stably high P3 amplitude produced by the medium trait-anxiety may be associated with consistent effort due to conscientiousness. The stably low P3 amplitude produced by the high trait-anxiety group was interpreted according to Attentional Control Theory (Eysenck et al., 2007). That is, attenuated P3 indicated reduced resource availability associated with interference as a result of poorer attentional control – most likely on the operation of disengagement.

Whereas the low trait-anxiety group produced equivalent P3 to the medium trait-anxiety group within the alternating-runs paradigm, they showed attenuated P3 within the task-cueing paradigm. This was attributed to passive withdrawal of resources associated with lower intrinsic motivation to perform on a task that is likely to have

presented little challenge. It is not unreasonable to consider that the effects for the low, medium and high trait-anxiety groups show consistency with the optimal arousal for performance effect (see Teigen, 1994) that was referred to in reporting the significant group x paradigm interaction for response latency. Indeed, review of the graph of this interaction in Figure 8.1 shows a somewhat similar pattern.

The pattern of effects observed for the repressor group provided some support for the late-stage processing advantage proposed in Vigilance-Avoidance Theory (Derakshan et al., 2007). Whereas the repressor group did not show processing equivalent to that of the low and medium trait-anxiety groups, they did show a pattern that appeared less affected by the demands on processing resources observable as a function of latent anxiety on the earlier components. This represents a clear divergence in processing to the between-group patterns observed for the amplitudes of each of the earlier components, particularly in relation to the high trait-anxiety group.

Nevertheless, the repressor group did show some similarity in processing to the low trait-anxiety group. Indeed, with the exception of local-global interference/facilitation associated with processing switch-cues, these groups maintained a very consistent profile across the interaction. Understanding the relationship between the repressor and high trait-anxiety groups is central to the current thesis. Hence, comparing the processing of these groups in conditions less laden with interference would be advisable.

P3 Latency

None of the relevant effects for P3 latency achieved, or approached significance; nor were these expected to.

Switch-Cueing Effects

N1 Amplitude

None of the relevant effects for N1 amplitude achieved, or approached significance. This is consistent with the null findings reported by Kieffaber and Hetrick (2005).

N1 Latency

As with N1 amplitude, none of the relevant effects for N1 latency achieved, or approached significance; nor were these expected to.

P2 Amplitude

None of the relevant effects for P2 amplitude achieved, or approached significance; nor were these expected to.

P2 Latency

Whereas P2 latency to switch-cues was not expected to vary across groups, the profile of the significant group x task interaction was of some interest. This showed a strong tendency for P2 produced by the high trait-anxiety and repressor groups to peak earlier than those produced by the medium and low trait-anxiety groups, respectively. This pattern is consistent with the vigilance-avoidance theory, in that the repressor and high trait-anxiety groups showed variation at this relatively early stage of processing. Perhaps the earlier peaks produced by these groups indicate expedited processing of predictable, non-critical events.

N2 Amplitude

There was no strong prediction for significant effects for N2 amplitude to switch-cues. It was, however, suggested that any effects would likely show N2 amplitude to increase as a function of latent anxiety (as was the case for the Stroop experiment in Chapter 7). The significant group x task interaction showed an unexpected profile. As expected, the low trait-anxiety group showed the smallest N2, with that by the medium trait-anxiety group being somewhat larger, and the greatest produced by the repressor group. The high trait-anxiety group, however, produced an unexpectedly low N2 that was equivalent to that of the low trait-anxiety group.

It is understandable that switch-cues would elicit N2. Aside from being relatively unpredictable, these events likely constitute bottom-up deviance from the configuration of the preceding task stimuli. It is also understandable that, relative to the low trait-anxiety group, the repressor group, and to a lesser (non-significant) extent, the medium

trait-anxiety group, allocated more attentional resources to processing switch-cues. It is puzzling, however, that the high trait-anxiety group was not similarly affected. According to both Attentional Control Theory (Eysenck et al., 2007) and Vigilance-Avoidance Theory (Derakshan et al., 2007) the high trait-anxiety group would be expected to engage similar levels of attentional resources toward conducting the processing associated with conflict monitoring. Further, this would also be expected according to the broader pattern of effects relating to these groups. Unfortunately, however, the lack of such an effect goes unaccounted for, at present.

N2 Latency

None of the relevant effects for N2 latency achieved, or approached significance; nor were these expected to.

P3 Amplitude

None of the relevant effects for P3 amplitude achieved, or approached significance; nor were these expected to.

P3 Latency

As with P3 amplitude, none of the relevant effects for P3 latency achieved, or approached significance; nor were these expected to.

Summary of Task Switching Effects

The strength and consistency of the effects observed for response latency and accuracy provided unequivocal support for the validity of the task-switching methodology employed in the present study. The moderated switch-cost found within the task-cueing paradigm, was attributed to the increased preparation time, and prospective interference of task-set inertia afforded by the novel stimulus attributes of the cue. The single group effect for the performance measures involved the repressor group achieving greater accuracy on the global task within the task-cueing paradigm compared to the alternating-runs paradigm. This effect showed strong concordance with

that observed for N1 latency, whereby processing by repressors was differentially affected by the task-cue and local-global interference.

In accounting for these findings, it was proposed that repressors may possess a characteristic bias toward more compartmentalised processing, which results in enhanced attention to the discrete stimuli. It was also proposed that this bias may have been offset in the task-cueing paradigm through the priming of global processing effected by the reading of the cue instruction. It was further suggested that these effects, in particular combination, may have led to premature passage of irresolute information; subsequently compromising the performance accuracy of the repressor group.

The sensitivity of N1 produced by the repressor group to task-cueing was supported by the latency data. Across the entire group x paradigm x trial interaction, the repressor group showed both the earliest and latest N1 peaks. These were both in response to switch trials. Whereas these effects were not confirmed by post-hoc testing, the repressor showed a tendency to produce the earliest N1 in response to switch trials within the task-cueing paradigm. Within the alternating-runs paradigm, however, the opposite was the case, with the repressor group producing the latest N1 of any group.

The trend for N1 amplitude to increase as a function of latent anxiety suggests that the repressor group found the processing at this stage particularly demanding. Given the prospect that N1 may reflect the initial functional integration of multiple sources of information at early selective attention (Wascher et al., 2009), it may be that this extra processing intensity was associated with the reconciliation of local-global processing, as a result of bias for elemental processing. Regardless, the analyses of the response accuracy and N1 latency data clearly indicate that both task-cueing and local-global processing differentially, and almost singularly, impacted the way repressors processed task-switches.

The repressor group also appeared most affected by interference during the processing indexed by P2. The lower P2 by repressors, and to a lesser (non-significant) extent, the high trait-anxiety group was considered to indicate lower interference reconciliation associated with stimulus discrimination. Further evidence of the susceptibility of the repressor group to interference was apparent within the significant main effect for N2 amplitude.

The tendency for the repressor group to engage more resources toward conflict monitoring was significant only in relation to the low trait-anxiety group. Whereas the divergence between the repressor and low trait-anxiety groups is consistent with the vigilance-avoidance account, the relative equivalence of the medium and high trait-anxiety groups is less so. The profile of group processing for N2 latency also deviated from that of the earlier components. The high trait-anxiety group showed a clear tendency to produce N2 that peaked later than each of the other groups. Whereas this effect was confirmed as significant, the apparent similarity in processing time by the other three groups was interesting. When taken together with the results for N2 amplitude, it appears that the repressor group effected greater processing speed and intensity than the low trait-anxiety group. Hence, processing at the N2 stage may represent the beginnings of divergence from the pattern whereby effects have tended to correspond with latent anxiety.

The apparent increased resource allocation to N2-related processing by the repressor group was considered to reflect management of conflict associated with coactive incompatible response tendencies (see Folstein & Van Petten, 2008 for a review). Hence, the current results concur with those found for Stroop interference in the previous experiment (Chapter 7), and present a strong case for the susceptibility of the repressor group to interference from unwanted information at the stage of conflict monitoring associated with response selection. Nevertheless, the speed at which the repressor group accomplishes this may speak to some flexibility in the operation of this processing. Indeed, comparison of the group processing profiles across N2 and P3 suggests that N2-related processing may mark a watershed in terms of bottom-up interference.

As expected, P3 amplitude showed a very strong attenuation on switch trials. The attribution of this to reduced resource availability as a consequence of task difficulty (per, Donchin, 1981; Kok, 2001) was also proposed to account for the stable effect across the significant group x paradigm x task x trial interaction, whereby the high trait-anxiety group produced the lowest P3 amplitudes, and the medium trait-anxiety group the highest. The apparent tendency for the low trait-anxiety group to produce lower P3 within the task-cueing paradigm was attributed to passive withdrawal of resources

associated with lower intrinsic motivation to exceed task demands. Further, a parallel was drawn between the amplitude profile of the low, medium and high trait-anxiety groups and the optimal arousal for performance effect (see Teigen, 1994).

The overall pattern of P3 amplitude produced by the repressor group was particularly interesting. Whereas the P3 of the repressor group did not show processing equivalent to that of the low and medium trait-anxiety groups, it did appear less affected by the demands on processing resources observable as a function of latent anxiety on the earlier components; particularly relative to the high trait-anxiety group. Although not supported by significant post-hoc tests, this tendency is nonetheless consistent with the late-stage processing advantage proposed by Vigilance-Avoidance Theory (Derakshan et al., 2007), whereby repressors are considered capable of superior inhibition of attention to unwanted information.

The switch-cues data also showed a pattern consistent with a vigilance-avoidance approach. This involved a strong tendency for P2 produced by the high trait-anxiety and repressor groups to peak earlier than those produced by the medium and low trait-anxiety groups, respectively. It was suggested that this may indicate expedited processing of predictable, non-critical events, that is, early recognition of stimulus-response associations relating to less-pressured response demands.

The effects for N2 amplitude to switch-cues also showed some consistency with the vigilance-avoidance account. As may be expected, relative to the low trait-anxiety group, the repressor group, and to a lesser (non-significant) extent, the medium trait-anxiety group, allocated more attentional resources to processing switch-cues. What did not accord with Vigilance-Avoidance Theory (Derakshan et al., 2007), however, was the observation that the high trait-anxiety group did not. Indeed, this deviation defied explanation. Overall, the ERPs to switch-cues did not reveal a great deal of information. Nevertheless, as noted earlier, given the likely ability of switch-cues to initiate task-set reconfiguration processes, it is important to seek understanding of the processing involved.

Indeed, improved understanding of the processes investigated within the current study may be achieved by coding each stimulus according to position within a sequence (e.g., Karayanidis et al., 2003). This would enable investigation of sequencing effects

such as those involved in post-switch adjustment. Further, this would also allow for group differences in preparation to be assessed. In addition, changing the nature of the task-cueing process may allow tighter comparison of the paradigms. For instance using stimulus colour to indicate tasks (e.g., Wylie et al., 2003) would not only eliminate facilitation of task-set reconfiguration afforded by cue presentation time, it would eliminate the prospect of interference of task-set inertia that may result from the physical presence of a cue. Finally, given the prospect of local-global interference, particularly for the repressor group, coding according to congruence of the local and global features would allow more specific analysis.

Conclusion

Overall the performance and ERP data showed convincing evidence of a classic switch-cost effect. The ERP data showed sensitivity to the effects of task-cueing and Stroop-type interference from the bivalent stimuli comprising the number-numerosity task. There was also evidence of interference consistent with a global precedence effect. Whereas this tended to be negligible, overall, the repressor group appeared singularly sensitive to this when conducting N1-related processing. The coherent pattern associated with this was consistent with the proposition that repressors may possess a bias toward enhanced attention to discrete elements; and that such a bias may reflect a propensity for compartmentalised processing of information that might be considered characteristic of repressors.

Overall, the majority of findings involving group differences were consistent with both Attentional Control Theory (Eysenck et al., 2007) and Vigilance-Avoidance Theory (Derakshan et al., 2007). In the case of Attentional Control Theory, interference is said to increase as a function of trait-anxiety, due to the associated poor attentional control. In the case of Vigilance-Avoidance Theory, early processing is impaired as a function of latent trait-anxiety, due to interference as a result of heightened threat vigilance. At later stages, however, repressors are considered to experience less interference due to a superior ability to divert attention from undesirable information.

Indeed, the N1, P2 and N2 components all showed a pattern whereby amplitudes increased (for N2 and N1), or decreased (for P2) as a function of latent anxiety. The first

evidence of deviation from this appeared on N2 latency, where the high trait-anxiety group showed a clear tendency to peak latest, whereas the other three groups showed quite similar latencies. Taken together with the results for N2 amplitude, it appears that the repressor group effected greater processing speed and intensity than the low trait-anxiety group. The proposal that this may represent the beginnings of divergence from the pattern whereby effects have tended to correspond with latent anxiety was supported by the P3 amplitude data. Whereas the P3 amplitude produced by the repressor group did not quite show processing equivalent to that of the low and medium trait-anxiety groups, it did appear less affected by the demands on processing resources relative to the high trait-anxiety group.

Overall, the convergent evidence from the present study was more consistent with the two-stage model of attentional processing in repression proposed in Vigilance-Avoidance Theory (Derakshan et al., 2007). The primarily exogenous N1 and P2 components clearly represented the less-controlled 'vigilance' stage, with the principally endogenous P3 component representing the more-controlled 'avoidance' stage. Whereas the N2 component appeared heavily influenced by bottom-up interference, there was also evidence of top-down influence over attentional processing strategy. This may constitute evidence of the proposed flexibility of selective attentional control by repressors.

The stable pattern for early attentional processing to vary as a function of latent anxiety provided strong evidence for the divergent validity of the construct of repressive coping style. The typically observed significant differences between the amplitudes produced by the repressor and low trait-anxiety groups distinguish these as sub-groups of people who report low trait-anxiety. Further, the stable tendency for the repressor group to exceed the processing extremity of the high trait-anxiety group suggests these groups did not engage in equivalent processing. Indeed, the results indicated that the repressor group were more susceptible to interference from extraneous information.

In further support of Vigilance-Avoidance Theory (Derakshan et al., 2007), the repressor group showed later-stage processing that trended away from that of the high trait-anxiety group, and toward that of the low and medium trait-anxiety groups. This was attributed to improved top-down control over interference by repressors. Together,

the findings of the present study support an attentional processing style by repressors that is reasonably consistent with the two-stage model proposed in Vigilance-Avoidance Theory (Derakshan et al., 2007). Whereas these findings were not always supported by strong effects, the observation of these in threat-absent conditions within a lengthy experimental session suggests the existence of a characteristic processing style that operates independently of perceived threat.

Despite the overall consistency of findings within the present study, aspects of the relationship between the repressor and low trait-anxiety groups at later-stage processing remain poorly understood. For instance, whereas these groups showed very similar processing profiles for P3 amplitude, there was a clear difference in the management of local-global interference/facilitation when processing cued switch trials. Given the lack of group effects found for P3 to the Stroop interference in the experiment presented in the previous chapter, further investigation is warranted. The results of the present study also suggest that repressors may possess a characteristic bias toward more compartmentalised processing, which results in enhanced attention to the discrete stimuli. This prospect is also worthy of further investigation.

Gaining a clearer understanding of the relationship between the low trait-anxiety and repressor groups on late-stage attentional processing would be assisted by reducing the complexity of task processing. Conversely, investigation of the prospect that repressors may engage in enhanced attention to the discrete stimuli would be aided by increasing the number of stimulus events to be simultaneously processed. Dual-task paradigms are able to facilitate both of these goals. Hence, a dual-task experiment was conducted in order to investigate the prospect of variance in attentional resource allocation as a function of latent trait-anxiety. This is presented in Chapter 9.

Chapter 9: Dual-Task Processing

The broader scope of the current thesis concerns the prospect of differential selective attentional processing between individuals classified as either, Low Trait-Anxious, High Trait-Anxious, or Repressors in an emotionally neutral context. The experiments presented in the previous two chapters were designed to investigate strategic differences in selective attentional processing. The results of the Stroop-interference experiment presented in Chapter 7 showed no evidence in support of the proposition that repressors possess superior ability to inhibit task-irrelevant information. There was, however, clear evidence found for the sensitivity of ERPs to variations in cognitive resource allocation to attentional processing, as a function of latent trait-anxiety.

The results of the task-switching study presented in Chapter 8 showed evidence consistent with both Attentional Control Theory (Eysenck et al., 2007) and Vigilance-Avoidance Theory (Derakshan et al., 2007). In the case of Attentional Control Theory, interference was shown to increase as a function of trait-anxiety, due to the associated poor attentional control. In the case of Vigilance-Avoidance Theory, early processing was impaired as a function of latent trait-anxiety, whereas repressors appeared to experience less interference compared to high trait-anxious individuals. The findings also suggested that repressors may possess a characteristic bias toward more compartmentalised processing, which results in enhanced attention to the discrete stimuli. Further, there was some indication that at later stages of selective attention the processing style of repressors may have shifted in alignment from characteristic of high trait-anxious individuals to low trait-anxious individuals.

In order to investigate the prospect of these attentional processing characteristics an experimental paradigm was required that could a) constrain the qualitative aspects of cognitive processing while allowing manipulation of processing demand, and b) provide opportunity for investigation of prospective bias toward discrete stimulus elements, and c) allow these to be measured using ERPs. Dual-tasks paradigms are particularly well suited to this approach. Hence, a dual-task paradigm was adopted for the present experiment.

Dual-Task Processing

Performing two tasks at once, or in close succession, typically results in performance costs compared to singular activities (Bonnel & Haftser, 1998; Kok, 1997, 2001; Lehle, Steinhauser, & Hübner, 2009; Pashler, 1994; Szameitat, Schubert, Müller, & von Cramon, 2002; Tombu & Jolicœur, 2005). In experimental contexts these costs are typically observed as increased response times and/or error rates (Szameitat et al.); and are generally referred to as the result of *dual-task interference* (Szameitat et al.; Tombu & Jolicœur). While the precise causes of dual-task interference continue to be debated in the literature (Bonnel & Haftser; Tombu & Jolicœur), there is consensus that they are a reflection of the limited capacity of the human information processing system (Bonnel & Haftser; Heuer, 1996; Kok, 1997, 2001; Lehle et al.; Pashler; Szameitat et al.; Tombu & Jolicœur).

The fundamental basis of the dual-task paradigm is the concurrent performance of two qualitatively distinct tasks (Kok 1997, 2001; Lehle et al., 2009; Pashler, 1994). The underlying rationale of this method is that concurrent task performance promotes competition for limited processing resources (Kok, 2001; Lehle et al.). The conjecture around dual-task interference centres on the way attentional resources are shared between the tasks.

Many researchers have offered evidence for the argument that a central processing bottleneck requires that the two tasks can only be processed serially, in a time-sharing arrangement requiring back-and-forth switching (e.g., de Jong, 1993; Meyer & Kieras, 1997; Pashler, 1994; Pashler & Johnston, 1989; Schubert, 1999). More recent work, however, has provided evidence suggesting that processing resources can be shared between tasks in a graded manner (e.g., Hübner & Lehle, 2007; Lehle et al., 2009; Miller, Ulrich, & Rolke, 2009; Tombu & Jolicœur, 2005). Hence, it appears that dual-task processing may be accomplished in a more serial or a more parallel fashion (Lehle et al.), suggesting that any central bottleneck may be strategic, rather than structural (Pashler).

The notion of the ability to divide attentional resources in a graded manner is consistent with single (e.g. Kahneman, 1973) and multiple (e.g., Navon & Gopher, 1979; Wickens, 1980) resource theories. These theories posit that cognitive processes are

performed through the allocation of processing resources from a limited capacity pool, or pools. Here, performance is said to suffer when processing demands exceed processing capacity; the greater the demands of a task, or process, the greater the demand on cognitive resources. Accordingly, dual-task interference occurs as a result of overload, in that task demands exceed available processing resources. When the demands of dual-task performance exceed resource capacity, performance efficiency and, or effectiveness is affected (Heuer, 1996; Kok, 1997; Lehle et al., 2009; Wickens, 2008).

Regardless of the underlying mechanisms involved, dual-task performance requires dynamic attentional resource allocation. Such dynamic mobilisation assumes concomitant demand on the flexibility of the attentional system. Given this, a dual-task paradigm provides an excellent opportunity to investigate prospective differences in attentional resource allocation processes of groups dissociable in terms of trait-anxiety or repressor status.

Dual-Task Paradigms

As mentioned earlier, dual-task paradigms are based on the concurrent performance of two qualitatively distinct tasks (Kok, 1997, 2001; Lehle, et al., 2009; Pashler, 1994). The processing demands required to perform these tasks can be varied in terms of difficulty and/or priority. The underlying rationale here is that increasing the difficulty or priority of one task will result in a reduction in resources available for the other task (Kok, 2001). Hence, dual-tasks provide a useful method for investigating the functional processes involved in attentional resource allocation (Heuer, 1996).

Dual-task combinations typically comprise an auditory and a visual modality. For the auditory task an oddball paradigm is commonly used (Meinhardt & Pekrun, 2003). Visual tasks often vary, though visual tracking paradigms have been used to elicit continuous attentional demand (e.g., Isreal et al., 1980a, 1980b). Participants are usually required to respond to target stimuli by counting or button press. Unfortunately, performance-based measures such as response latency and accuracy provide a poor index of the allocation of processing resources (Meinhardt & Pekrun). Resource

allocation can, however, be directly investigated through the employment of a dual-task paradigm using ERPs (Meinhardt & Pekrun).

ERPs in Dual-Task Paradigms

ERPs are particularly well suited to indexing resource allocation processes in dual-task paradigms through their capacity to provide sensitive information about the characteristics of phasic energy expenditure in the brain with high temporal resolution (Kok, 1997). The literature on dual-task experiments using ERPs is not large, and there is considerable qualitative variation across the tasks employed. This has been suggested as a reason for the rather contradictory results provided by neuroimaging studies investigating the functional neurophysiology of dual-task performance (Szameitat, et al., 2002). Nevertheless, some effects involving the N1 and P3 components have been shown to be reliable.

Several dual-task studies have shown increases in N1 amplitude elicited by target stimuli in auditory and visual modalities according to resource allocation (Hink, Van Voorhis, & Hillyard, 1977; Parasuraman, 1978; Van Voorhis & Hillyard, 1977). N1 is commonly interpreted as reflecting allocation of perceptual resources (Kieffaber & Hetrick, 2005; Kok, 1997, 2001; Mangun & Hillyard, 1990, 1991). Kok (1997), however, suggests that that within the framework of multiple resource theory, these perceptual resources can be further divided into modality-specific and non-specific sub-components.

A large body of evidence has accumulated demonstrating the P3 component to be a reliable index of the allocation of processing resources in dual-task performance (Kok, 1997, 2001; Meinhardt & Pekrun, 2003). Several studies have shown P3 amplitude to increase or decrease systematically according to the positive relationship shared with task difficulty (Donchin, Miller, & Farwell, 1986; Kramer, Sirevaag & Braune, 1987; Sirevaag, Kramer, Coles & Donchin, 1989; Wickens et al., 1983). This pattern is consistent with the resource trade-offs predicted by resource theories of information processing (e.g., Kahneman, 1973; Meinhardt & Pekrun, 2003; Navon & Gopher, 1979; Wickens, 1984).

Rationale

There is strong evidence of variation in the psychological management of information interpretable as signifying potential threat according to both trait-anxiety and repressor status. In addition, there is evidence that trait-anxiety has been shown to affect eye movement in neutrally-valenced spatial attention tasks (Derakshan et al., 2009). In addition to this, as part of Attentional Control Theory, Eysenck et al. (2007) suggest that, even in neutrally-valenced tasks, trait-anxiety and repressor status will reduce task processing efficiency without necessarily reducing task-processing effectiveness.

Further, the results of the task-switching study presented in Chapter 8 showed evidence consistent with attentional control varying as a function of latent trait-anxiety. This included differential processing profiles observed for repressors at earlier and later stages of selective attention to task performance. In addition, the results associated with earlier processing suggested that repressors may engage in enhanced attention to discrete stimulus elements.

Not only does dual-task performance require dynamic attentional resource allocation, it allows for controlled manipulation of demand on the flexibility of the attentional system. This includes the ability to vary the amount of discrete events to be processed. Further, dual-task paradigms can be very amenable to ERP methodology. Given these attributes, it is somewhat remarkable that the literature on ERP correlates in dual-task performance is not more substantial.

Hence, the aim of the present study was to use dual-task processing to investigate potential differences in operational attention between individuals classified as either low trait-anxious, medium trait-anxious, high trait-anxious, or repressors, in an emotionally neutral context. More specifically, the interest was in investigating characteristic management of attentional processing at load; particularly in relation to the number of discrete stimuli. This involved use of ERP metrics in addition to behavioural performance data.

Hypotheses

Unfortunately, there is a lack of substantial evidence in the literature to guide definitive hypotheses relating to the aim of the present experiment. As mentioned earlier, a desultory body of research has produced conflicting findings emanating from broad methodological variation. This has frustrated the clear understanding of ERP correlates. This is compounded by the dearth of research on the correlates of latent trait-anxiety on attentional resource allocation processes in dual-task situations. Hence, the ERP and group effects proposed are done so with caution.

Performance Measures

Response latencies were expected to be greater to rare tones than to common tones. Further, response latencies to both visual and auditory tasks were expected to be longer in the more difficult condition. Response latencies were also expected to increase with decreased attentional priority. Response latency was not expected to be sensitive to group differences.

Response accuracy was expected to show inverse effects to response latency. That is, response accuracy would be lower to rare tones than to common tones, and lower for both visual and auditory tasks in the more difficult visual condition. Further, response accuracy was expected to decrease as a function of decreasing attentional priority. Response accuracy was not expected to vary by group.

ERP Measures

The lack of definitive existing research into the earlier ERP correlates in dual-task performance, mentioned earlier, thwarted confident formulation of strong hypotheses relating to differential attentional resource allocation as a function of group. Nevertheless, tentative predictions were made based on the combination of existing theory and speculation based on the results of the Stroop-Interference and Task-Switching studies reported in Chapters 7 and 8, respectively. As will be discussed in the Method and Results sections of the present chapter, only ERP data for the rare tones within the secondary task were subjected to inferential analyses.

Overall, it was considered that group effects would be more likely under conditions of higher attentional load. That is, when the primary (visual) task was more difficult, and/or, priority to the secondary (auditory) task was lower. Given the trends observed for the N1 component in Chapters 7 and 8, it was considered that effects involving N1 amplitude and latency would show increases in these dimensions as a function of latent trait-anxiety. Further, on the basis of the effect for N2 amplitude to increase as a function of latent trait-anxiety, which showed the difference between the low trait-anxiety and repressor groups to be significant across both Chapters 7 and 8, it was considered likely that this effect would be observed within the current experiment also. Notwithstanding the overall effects proposed as a function of load, groups were not expected to differ on P2. It was anticipated that any group effects for P3 would involve differential processing by the repressor group.

Method

Participants

The prospective participant pool referred to in the present study was independent of that shared by the Stroop-interference and task-switching studies presented in Chapters 7 and 8. Initially 300 first-year psychology students and five post-graduate psychology students completed the Trait version (Form Y-2) of Spielberger's (1983) State-Trait Anxiety Inventory for Adults (STAI-T). Missing values were treated as described in Chapter 7. The data from three respondents were withdrawn due to having greater than two violations concerning missing data and/or multiple responses to an item. Twelve respondents failed to indicate a score on one item; one did not respond to two items. Three respondents reported two values on one item, while one respondent reported two values on two items.

Following this treatment of the initial data, the sample comprised 302 people (227 females) ranging between 17-65 years of age. These data were further reduced, according to processes detailed in Chapter 7, to create a pool of prospective participants.

The characteristics of these samples are presented for comparison with those of the eventual experimental participants and the relevant normative data from the STAI Manual (Spielberger, 1983) in Table 9.1.

Table 9.1
Comparison of initial respondents, experimental pool, experimental participants, and normative samples on sample size and STAI-T score characteristics

Sample	N	Mean	SD	Minimum Score	Maximum Score
Initial Respondents	302	43.33	11.14	20	74
Participant Pool	168	44.82	10.12	23	74
Experiment Participants	49	44.16	10.85	23	70
Female University Students (STAI Manual)	481	40.40	10.15	n/a	n/a
Working Females Aged 19-39 (STAI Manual)	210	36.15	9.53	n/a	n/a

Note. The STAI (Form Y) Manual (Spielberger et al., 1983) provides normative data only for select samples, with data for males and females presented separately.

The 168 potential participants comprising the Participant Pool, all of whom were female, were categorised into five groups according to their STAI-T scores: *Low Anxious*, 23-37 (n=38); *Low-Medium Anxious*, 38-41 (n=27); *Medium Anxious*, 42-45 (n=35); *Medium-High Anxious*, 46-50 (n=21); and *High Anxious*, 51-74 (n=47). These five groups were created in order to provide greater distinction between the groups of experimental interest through disregarding respondents in the groups intermediating these; namely the Low-Medium and Medium-High groups.

The separation, on STAI-T scores, achieved between the Low, Medium and High Anxious groups that comprised the prospective participant pool is displayed in Table 9.2. Also presented in Table 9.2 are the STAI-T characteristics of the eventual experimental groups. Included here is a *Repressor* group. Repressors were categorised

according to an adaptation of the process used by Weinberger, Schwartz, and Davidson (1979). Although repressors have been identified using a number of systems, the combination of low trait-anxiety and high psychological defensiveness used by Weinberger et al. remains the most influential (Derakshan et al., 2007).

Weinberger et al. (1979) identified repressors as those who scored 13 or below on the Manifest Anxiety Scale (Taylor, 1953), as well as 19 or above on the Marlowe-Crowne Social Desirability Scale (MCSDS) (Crowne & Marlowe, 1960). This process has since been adapted, with more contemporary research typically maintaining the MCSDS and the cut-off score of 19, but substituting the STAI-T in place of the Manifest Anxiety Scale (e.g., Bar-Haim, Lamy & Glickman, 2005; Bromfield & Turpin, 2005; Dawkins & Furnham, 1989; Derakshan & Eysenck, 2001; Calvo & Eysenck, 2000; Fox, 1993; Fox, 1994). Hence, in the present experiment, those participants from the low in trait-anxiety pool who scored 19 or above on the MCSDS were subsequently classed repressors.

Table 9.2
Comparison of the Low, Medium and High Anxious groups, and the Repressor group from the participant pool and the experimental groups on sample size and STAI-T score characteristics

Sample	N	Mean	SD	Minimum Score	Maximum Score
High Pool	47	57.68	6.13	51	74
High Experimental	16	56.88	6.02	51	70
Medium-High Pool	21	47.86	1.39	46	50
Medium Pool	35	43.31	0.96	42	45
Med. Experimental	16	43.50	0.97	42	45
Low-Medium Pool	27	39.37	1.15	38	41
Low Pool	38	32.50	4.23	23	37
Low Experimental	10	33.50	3.81	24	37
Repressor Group	7	31.86	5.33	23	37

The experimental sample comprised 49 right-handed female psychology students at the University of Tasmania aged between 17 years, 10 months and 28 years, 10 months (*M* = 20 years, 0 months, *SD* = 2 years, 6 months). Of these, 47 were first year students who participated in exchange for partial course credit, with the remaining two being psychology post-graduate students volunteering their time. The characteristics of the experimental sample are presented in Table 9.1.

ANOVAs conducted on mean age and STAI-T scores found that the experimental groups were not significantly different on mean age, $F(3,45)=0.61$, MSE=970, $p=.612$, however a significant main effect was found for total STAI-T score, $F(3,45)=83.63$, MSE=19.09, $p<.001$, $\eta^2=.848$. Tukey HSD post-hoc tests revealed that the mean STAI-T score for the High-Anxious group was significantly higher than that of the Medium-Anxious group, which was significantly higher than the mean total STAI-T score for the Low-Anxious and Repressor groups (ps<.001). The Low-Anxious and Repressor groups did not differ (p=.871). These means and standard deviations are presented in Table 9.2.

Materials, Apparatus & EEG Recording

Materials, apparatus and EEG recording were as described in Chapter 7. The single exception to this was that stimuli were presented on a 17-inch CRT monitor.

Tasks and Stimuli

Visual task and stimuli

The present experiment used a dual task similar to that described by Isreal, Wickens, Chesney, and Donchin (1980). The primary task involved visual tracking of continuously moving squares (5x5mm) presented as blue on a grey field. Triangles (6 x 6 x 6mm) were also presented in blue as distracters. All stimuli travelled linearly across the 195mm x 140mm field at a rate of 30mm per second in a random direction between 10º-170º (relative to 0º vertical). Once leaving the field stimuli immediately re-entered as described above. Every 6-10 seconds (M=8s) one of the shapes changed direction by 60º if the pre-change direction was between 10º-90º or by -60º if the pre-change direction was otherwise. No stimulus changed direction when it was within 18mm of

another or the edge of the field. Direction changes did not occur within 1000ms of auditory stimuli in dual-task conditions. These constraints and the random nature of stimuli travel and order of presentation meant that the number of course changes for targets and distracters varied, typically between 30 and 40.

The visual task incorporated two levels of difficutly. The *Less* difficult task comprised two of each stimulus, whereas the *More* difficult task comprised four of each stimulus. Participants were required to respond as quickly as possible only to course changes of squares by pressing the space bar on the keyboard with the left index finger. Responses were considered valid if they were registered within 1000ms of the onset of the target event.

Auditory task and stimuli

The secondary task comprised auditory stimuli delivered binaurally through headphones as either low-pitched (1200 Hz) or high-pitched (1400 Hz) tone bursts (64 dB SPL, re 20 $\mu N/m^2$). One hundred tones were presented for 60ms every two seconds, with 70 (p=.7) being low-pitched and 30 (p=.3) high-pitched. The order of these was pseudo-randomised and always began with a low-pitched tone for reference. Participants were required to respond as quickly and accurately as possible to every tone by pressing the *zero* key on the number pad of the keyboard with the right index finger for low-pitched tones and the *Enter* key of the number pad with the right ring finger for high-pitched tones. Responses were considered valid if they were registered within 1000ms of the onset of the target stimulus.

Procedure

The initial procedure, up until the introduction of the experimental task, was identical to that described in Chapter 7. Participants were seated in a sound attenuated room at a distance of approximately 70cm from the monitor and given a general overview and demonstration of the task and response requirements. This was followed by a more specific instruction and practice session pertaining to the ensuing condition. In dual-task conditions participants were required to perform both the auditory and a visual task concurrently, allocating priority, or attention, to each task as instructed. The

three priority conditions were: 90% priority to visual task, 10% to auditory task; equal priority to each task; and 10% to the visual task, 90% to the auditory task.

Counterbalancing of the nine experimental conditions was conducted within two blocks: single-tasks and dual-tasks. The single-task block was always delivered first so as to provide extra practice toward mastery in preparation for the more demanding dual-tasks. Upon completion of each seven-minute condition participants were offered a break, following which they were instructed and offered practice on the next condition. With instructions, practice sessions and breaks the current experiment took approximately 60 minutes to complete. No participants reported, or appeared to experience, adverse reactions to the experimental procedure. An anonymous examiner of the present dissertation requested inclusion of data on the number of trials included in the ERP waveforms for each experimental group, in each condition. These are presented in Table 9.3.

Table 9.3
Comparison Across Groups on Numbers of Trials Included in ERP Waveforms to Novel Tones for Each Difficulty Condition and Task Priority (Numbers of Excluded Trials Appear in Parentheses).

			Easy			Difficult		
Group	N	100%	90%	50%	10%	90%	50%	10%
Repressor	7	183 (27)	174 (36)	163 (47)	169 (41)	184 (26)	162 (48)	164 (46)
High Trait-Anxiety	16	462 (78)	443 (97)	461 (97)	429 (111)	438 (102)	425 (115)	452 (88)
Med. Trait-Anxiety	16	477 (93)	455 (115)	490 (80)	438 (132)	469 (101)	455 (115)	472 (98)
Low Trait-Anxiety	10	277 (53)	292 (38)	277 (53)	279 (51)	298 (32)	263 (67)	276 (54)

Design

The present experiment incorporated both single-task and dual-task designs. The dual-task comprised a 4 [Group: Low Trait-Anxiety, Medium Trait-Anxiety, High Trait-Anxiety, Repressor] x 2 (Tone: Common, Rare) x 3 (Priority %: 90/10, 50/50, 10/90) x 2 (Difficulty: Less, More) mixed design. The single-task designs varied according to modality. The auditory task comprised a 4 x 2 (Tone) mixed design. The visual task comprised a 4 x 2 (Difficulty) mixed design. Following inspection of the ERP grand means, a further repeated measures factor was included for ERP analyses: Sagittal Site (Fz, Cz, Pz).

The behavioural dependent variables were response time (ms) and accuracy (percentages). The psychophysiological dependent variables were N1, P2, N2, and P3 amplitudes (μV) and latencies (ms). These ERP component parameters were defined after viewing the grand-average waveforms at locations of theoretical maxima (see Chapter 4); a process similar to that outlined in Wylie, Javitt, and Foxe (2003). The resultant ERP component amplitudes were ascertained as the maximum negative- or positive-going peaks, according to the polarity of the component, within the parameters reported in Table 9.4.

Table 9.4
ERP component parameters for peak detection (in milliseconds)

ERP Component	Visual Stimuli	Auditory Stimuli
N1	150-280	80-185
P2	250-375	170-265
N2	300-440	225-300
P3	380-700	280-500

Note. P2 was determined as the largest positive-going peak following N1 and N2 was determined as the largest negative-going peak occurring between P2 and P3 within the stipulated parameters.

Data Analysis

Regarding the analyses described in this section, it should be noted that where necessary, a Huynh-Feldt correction was applied to control for violations of sphericity. Further, Tukey HSD post-hoc tests were conducted to clarify the simple effects of significant interactions and main effects where necessary. All statistical tests were considered significant at alpha .05.

Behavioural Data

Single-Task

For the single-task, auditory task data were analysed by 4x2 (Tone: Common, Rare) mixed ANOVA. Visual task data were analysed by 4x2 (Difficulty: Less, More) mixed ANOVA. For the dual-task, behavioural data were data were analysed by 4 [Group] x 3 (Priority %: 90/10, 50/50, 10/90) x 2 (Difficulty) mixed ANOVA.

ERP Data

ERP data were limited to the auditory tone discrimination task. Given there were no laterality effects expected, grand mean waveforms (see Figures 9.3, 9.4, 9.5 and 9.6, in Results) were inspected for hemispheric asymmetry. As no such asymmetry was apparent, only the midline sites were retained. Analyses were conducted for each component according to maxima. The N1 component was analysed across both Fz and Cz. Analyses for P2 were constrained to Cz, whereas those for N2 were constrained to Fz. The P3 component was maximal across both Pz and Cz. As expected, there was a lack of substantial activity for the N2 and P3 components in response to Common tones. This was inconsequential to the aims of the current experiment. Indeed, as activity to Common tones was not of central interest to the present study, ERP analyses were limited to the Rare tone, as the target variable of the secondary task.

Single-task analyses of Rare tones varied by component according to the identified maximas. Both N1 and P3 underwent 4x2 (Sagittal) mixed ANOVA, whereas P2 and N2 were analysed by one-way between-groups ANOVA. For the dual-task, whereas each of

the four components underwent initial 4x3 (Priority %) x2 (Difficulty) mixed ANOVA, the N1 and P3 analyses included an additional factor of x2 (Sagittal).

Results

Behavioural Data

Raw data were participants' individual response times on correctly performed trials. Response times (ms) were converted to means, and correct responses to percentages of the total number of valid trials. These data were then subjected to repeated measures ANOVAs, with Huynh-Feldt correction to degrees of freedom where appropriate, according to dictates of the design. Tukey's HSD test was used to evaluate the significance of differences underlying main effects and interactions between factors, where necessary. Effects were considered statistically significant at, or below, p=.05. Only those results of theoretical significance are reported.

In the interests of focus and brevity, only effects of theoretical significance to the present study are reported. Given the centrality of group effects to the present study, all main effects for group were reported, whereas interactions involving group were reported only when these achieved or approached statistical significance. Other significant main effects were reported only for the purpose of demonstrating the validity of experimental manipulations.

Visual Task

Response Latency

Single-Task

The Group x Difficulty mixed ANOVA indicated non-significant effects for both the main effect for Group, $F(3,51)=1.20$, MSE=5550, p=.320; and the Group x Difficulty interaction. The main effect for Difficulty was found to be significant, $F(1,51)=21.39$, MSE=1863, $p<.001$, $\eta^2=.292$, and indicated that participants responded faster when the task was Less difficult (M=583.57, SEM=9.30) than when it was More difficult (M=624.84, SEM=8.48).

Dual-Task

The Group x Priority x Difficulty mixed ANOVA indicated the main effect for Group was not significant, $F(3,51)=1.06$, MSE=16414, $p=.323$. Whereas Group did not interact with Priority or difficulty, the main effect for Priority was shown to be significant $F(2,102)=20.69$, MSE=1937, $p<.001$, $\eta^2=.282$. The soundness of this effect was supported by the significant results of post-hoc tests. Response times to visual targets was significantly faster in the 90% priority condition (M=630.77, SEM=8.41) than both, the 50% priority condition (M=648.56, SEM=8.71) ($p=.014$), and the 10 % priority condition (M=672.02, SEM=8.21) ($p<.001$). Further, the difference between the 50% and 10% conditions was also significant ($p<.001$). The main effect for Difficulty was found to be significant, $F(1,51)=18.33$, MSE=2625, $p<.001$, $\eta^2=.255$, and indicated that participants responded faster when the task was Less difficult (M=637.36, SEM=8.71) than when it was More difficult (M=663.54, SEM=7.61).

Response Accuracy

Single-Task

The Group x Difficulty mixed ANOVA indicated non-significant effects for both the main effect for Group, $F(3,51)=1.28$, MSE=146.20, $p=.290$; and the Group x Difficulty interaction. The main effect for Difficulty was found to be significant, $F(1,51)=224.40$, MSE=69.00, $p<.001$, $\eta^2=.811$, and indicated that participants responded with much greater accuracy when the task was Less difficult (M=91.73, SEM=1.40) than when it was More difficult (M=66.00, SEM=1.63).

Dual-Task

The Group x Priority x Difficulty mixed ANOVA indicated the main effect for Group was not significant, $F(3,51)=0.90$, MSE=915, $p=.449$. Whereas Group was not found to interact significantly with Priority or Difficulty, the main effect for Priority was shown to be significant $F(2,102)=22.86$, MSE=150, $p<.001$, $\eta^2=.293$. Post-hoc tests indicated that the reduction in accuracy from the 90% priority condition (M=72.50, SEM=81.77) to the 50% priority condition (M=70.61, SEM=2.18) was not significant

(p=.167), whereas the relative reduction in accuracy between these two conditions and the 10% priority condition (M=61.21, SEM=2.26) was significant (ps<.001). The main effect for Difficulty was also found to be significant, F(1,51)=267.43, MSE=127, p<.001, η^2=.836. This indicated that participants responded with much greater accuracy when the task was Less difficult (M=79.11, SEM=1.90) than when it was More difficult (M=57.10, SEM=1.96).

Auditory Task

Response Latency

Single-Task

The Group x Tone mixed ANOVA indicated non-significant effects for both the main effect for Group, F(3,51)=0.27, MSE=6599, p=.846; and the Group x Tone interaction. The main effect for Tone was found to be significant, F(1,51)=92.92, MSE=1272, p<.001, η^2=.644, revealing a strong effect whereby participants responded to the Common tone (M=411.18, SEM=8.95) with much greater speed than the Rare tone (M=482.25, SEM=9.39).

Dual-Task

Whereas the Group x Tone x Priority x Difficulty mixed ANOVA indicated the main effect for Group was not significant, F(3,51)=0.70, MSE=49627, p=.554. The main effect of Tone was shown to be significant, F(1,51)=212.94, MSE=8068, p<.001, η^2=.795, revealing a very strong effect whereby participants responded significantly faster to Common tones (M=450.48, SEM=10.19), than Rare tones (M=561.11, SEM=10.08). The main effect of Priority was also shown to be significant, F(1.66,84.88)=59.05, MSE=4910, p<.001, η^2=.531. Post-hoc tests indicated that the increase is response latency to tones from the 90% priority condition (M=475.85, SEM=9.90) to the 50% priority condition (M=491.15, SEM=10.02) was not significant (p=.110), whereas the relative increase in response latency between these two conditions and the 10% priority condition (M=550.38, SEM=10.92) was significant (ps<.001).

The significant main effects for Difficulty and Priority trended toward being modified by the Group x Priority x Difficulty interaction, which approached

significance, $F(5.39,91.56)=2.17$, MSE=1411, $p=.059$, $\eta^2=0.113$. Figure 9.1 shows that, overall, the Medium Trait-Anxiety group appeared to respond fastest to targets. As discussed in relation to the significant main effect for Priority, response times to the 10% condition were clearly greater than the 50% and 90% conditions, Figure 1 shows this was particularly so for the High Trait-Anxiety and Repressor groups. Curiously, the Repressor and High Trait-Anxiety groups also appeared to respond slightly faster to auditory targets when the visual task was More difficult, when Priority to the auditory task was reduced to 50% and 10%. Further, when performing the auditory task under the reduced Priority conditions of 50% and 10%, the Repressor and High Trait-Anxiety groups appeared to respond slightly faster when the competing visual task was more difficult. No other interactions involving Group approached significance.

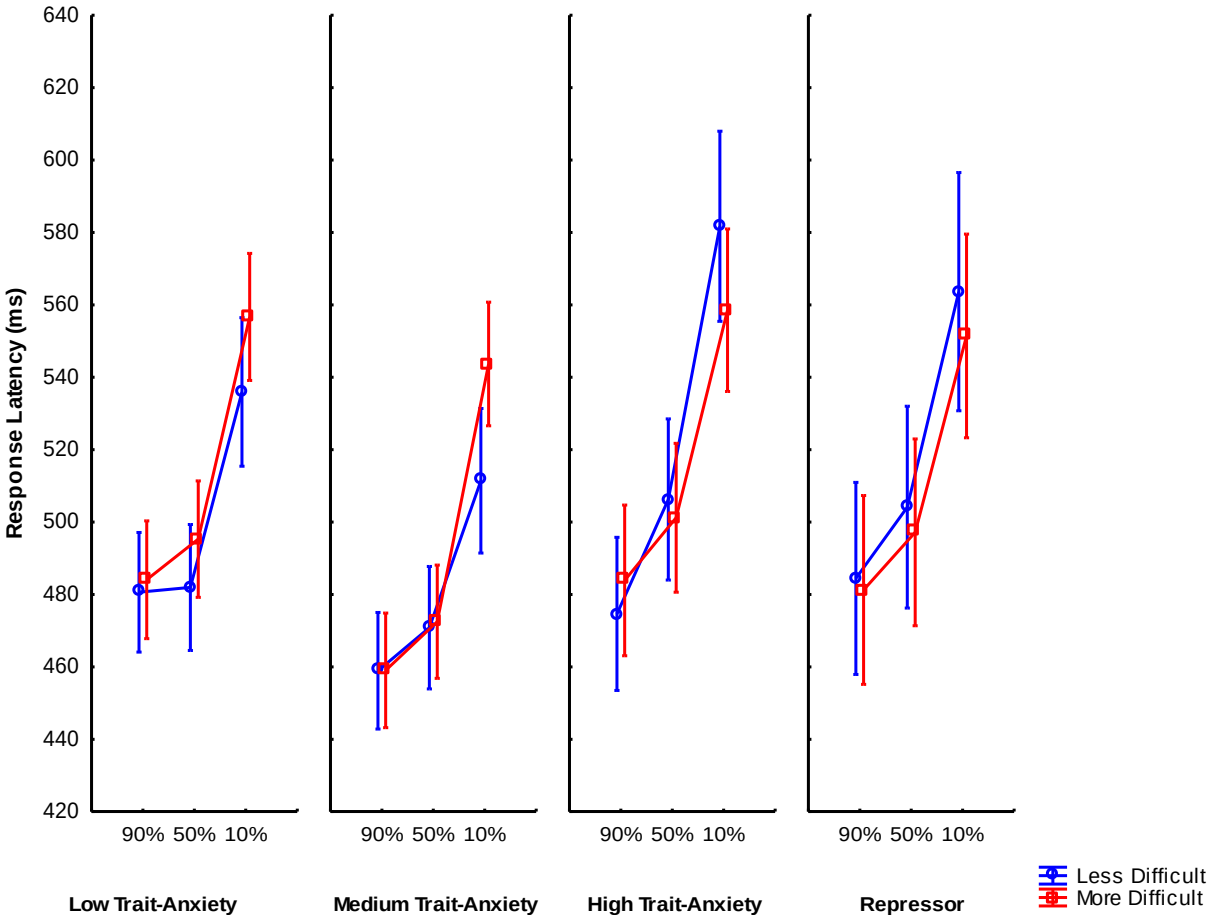

Figure 9.1. Response latency to auditory stimuli for each priority and difficulty level, for each of the four groups (vertical bars denote SEM).

Response Accuracy

Single-Task

The Group x Tone mixed ANOVA indicated the main effect for Group as approaching significance, $F(3,51)=2.65$, MSE=27.80, $p=.059$, $\eta^2=.135$. The main effect for Tone was significant, $F(1,51)=43.24$, MSE=22.80, $p<.001$, $\eta^2=.420$; as was the Group x Tone interaction, $F(3,51)=2.93$, MSE=22.80, $p=.042$, $\eta^2=.085$. As shown in Figure 9.2, accuracy across the Groups was equivalent when responding to the Common tone. This was not the case for the Rare tone, however. As indicated by the significant main effect for Tone, accuracy was lower in response to the Rare tone across the Groups. This was particularly the case for the Repressor group. Indeed, the results of the post-hoc tests for this interaction, presented in Table 9.5 (along with means and standard errors) showed response accuracy to Rare tones by the Repressor group to be significantly lower than each of the other Groups, with the exception of the Medium Trait-Anxiety group.

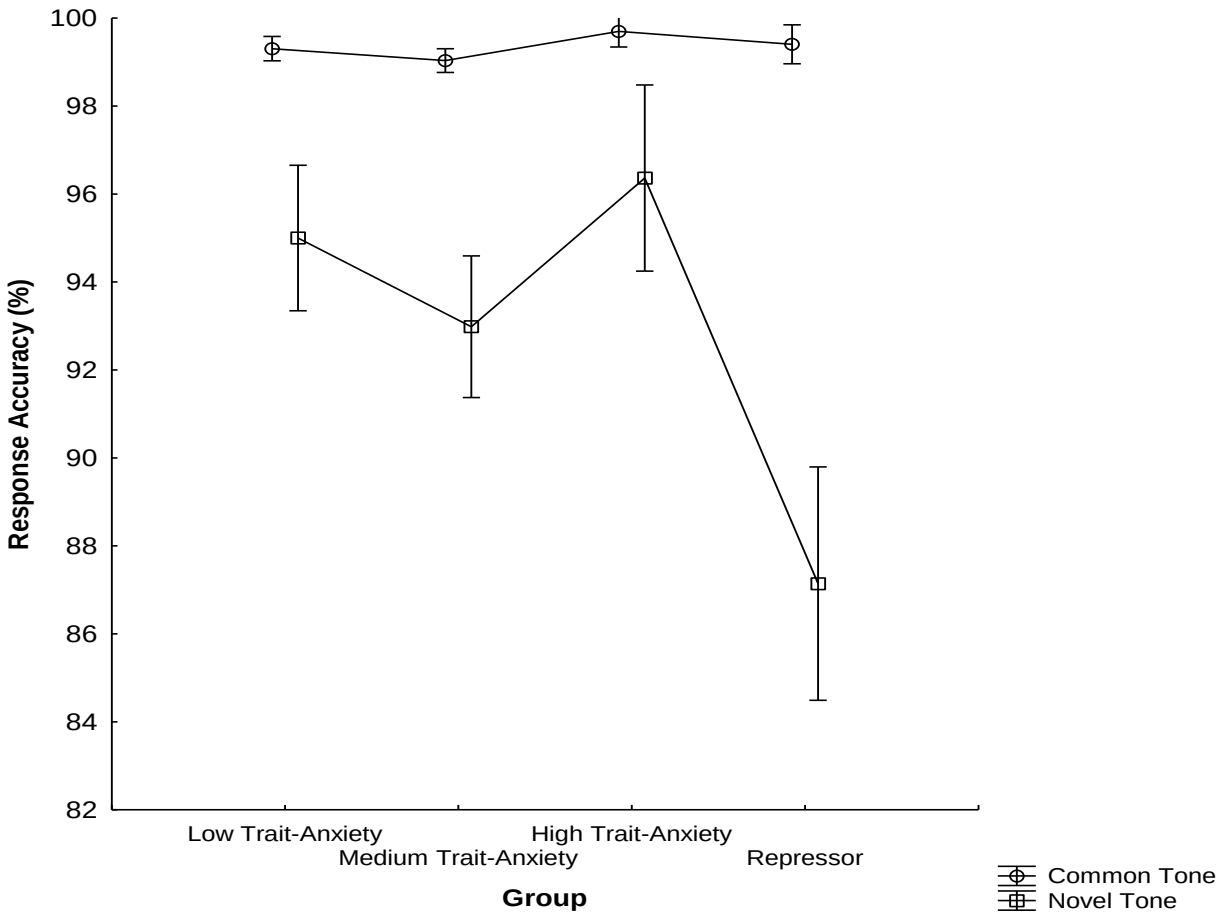

Figure 9.2. Response accuracy to auditory stimuli for each of the four groups (vertical bars denote SEM).

Table 9.5
Means, Standard Errors (in parentheses), and p-values from Tukey's Post-Hoc Tests for the Group x Tone interaction for Response Accuracy %

Group	Tone	Mean	Standard Error	*p*-value
Low Trait-Anxiety	Common	99.31	(0.28)	<.001
	Rare	95.00	(1.65)	.015
Med. Trait-Anxiety	Common	99.04	(0.27)	<.001
	Rare	92.98	(1.61)	.159
High Trait-Anxiety	Common	99.70	(0.35)	<.001
	Rare	96.36	(2.12)	.006
Repressor	Common	99.41	(0.44)	<.001
	Rare	87.14	(2.65)	

Note. Significance = *p*-value from Tukey's post-hoc testing of comparison against Response Accuracy to Rare Tones for the Repressor Group.

Dual-Task

The Group x Tone x Priority x Difficulty mixed ANOVA indicated the main effect for Group was not significant, $F(3,51)=0.77$, MSE=438, $p=.516$. Whereas no other interactions involving Group approached significance, the main effect of Tone was shown to be significant, $F(1,51)=78.06$, MSE=187, $p<.001$, $\eta^2=.587$, revealing a very strong effect whereby participants responded with greater accuracy to Common tones ($M=96.68$, $SEM=0.61$), than Rare tones ($M=86.47$, $SEM=1.36$). The main effect of Priority was also shown to be significant $F(2,102)=9.85$, MSE=58, $p<.001$, $\eta^2=.159$. Post-hoc tests indicated that the reduction in accuracy from the 90% priority condition ($M=93.01$, $SEM=0.71$) to the 50% priority condition ($M=92.09$, $SEM=0.93$) was not significant ($p=.484$), whereas the relative reduction in accuracy between these two conditions and the 10% priority condition ($M=89.63$, $SEM=1.26$) was significant ($p<.001$ and $p=.002$, respectively). The main effect for difficulty did not reach significance, $F(1,51)=2.35$, MSE=36, $p=.131$.

ERP Data

Grand mean waveforms for the Common and Rare tones within both the Less and More difficult conditions are presented in Figure 9.3. Further, grand mean waveforms for Common and Rare tones within each of the Priority conditions are presented in Figure 9.4. In addition to these, grand mean waveforms for each of the four groups are presented for Common tones and Rare tones in Figure 9.5. The grand mean waveforms presented in each of these three figures are scaled consistently. Whereas these figures show ERPs for midline sites only, full arrays are appended for inspection (see Appendices P, Q, R and S).

Presented in Figure 9.3 are the grand mean waveforms for both Tones at each level of task Difficulty. The N1 component is maximal across Fz and Cz, and shows little variation between Tone type or level of Difficulty. Indeed, effects of Difficulty did not appear for any of the components of interest. The P2 component is maximal at Cz and appears to be much greater to Common tones than Rare tones. The N2 was maximal at Fz, and P3 was maximal across Pz and Cz; however these two components were distinctive only for Rare tones. This is as would be expected, given N2 is associated with conflict detection during response selection (see Yeung & Cohen, 2006), and the attenuation of P3 varies as a function of probability (Kok, 2001). Further, the low probability of Rare tones is likely to be responsible for the P3a observable at Fz (see Comerchero & Polich, 1999; Polich, 2003).

Figure 9.4 shows the grand mean waveforms for both Tones at each level of Priority. As would be expected, the profiles relating to Tone-type for each of the components is as described for Figure 9.3. Indeed, there was little variation as a function of Priority apparent across all of the ERP components. The single exception to this is the attenuation of P3 within the 10% Priority condition, relative to the 50% and 90% conditions.

Presented in Figure 9.5 are the grand mean waveforms for Common tones for each of the four groups. The largest N1 appeared to be produced by the Repressor group, whereas the smallest appeared to be produced by the Medium Trait-Anxiety group. These differences were more evident at Cz than Fz. For the P2 component, the Repressor and Low Trait-Anxiety groups appeared to produce larger, later peaks than

the Medium and High Trait-Anxiety groups. As described in relation to Figure 9.3, activity consistent with N2 and P3 is relatively negligible.

Much more group variation is apparent within the grand mean waveforms for Rare tones for each of the four groups, also presented in Figure 9.5. Again, N1 appears largest for the Repressor group, particularly at Cz. Whereas P2 is relatively small, it appears that the Medium Trait-Anxiety group produced more activity than the other three groups. This was also the case for N2, where inspection of Fz shows that less activity was produced by the Low and High Trait-Anxiety groups, with the Repressor group producing the least of all. For P3, however, the Repressor group, along with the High Trait-Anxiety group, appeared to produce the largest components, with the relative difference between these groups and the Low and Medium Trait-Anxiety groups being less pronounced at Pz than at Cz.

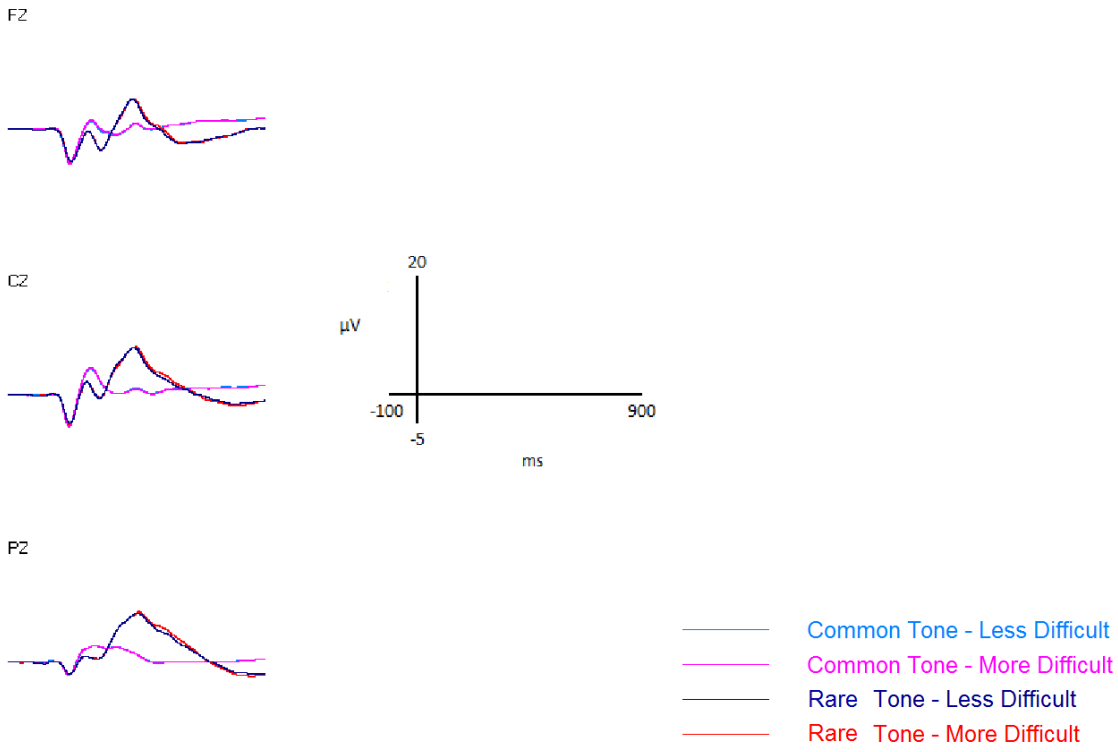

Figure 9.3. Grand mean waveforms for common and rare tones at both levels of task difficulty.

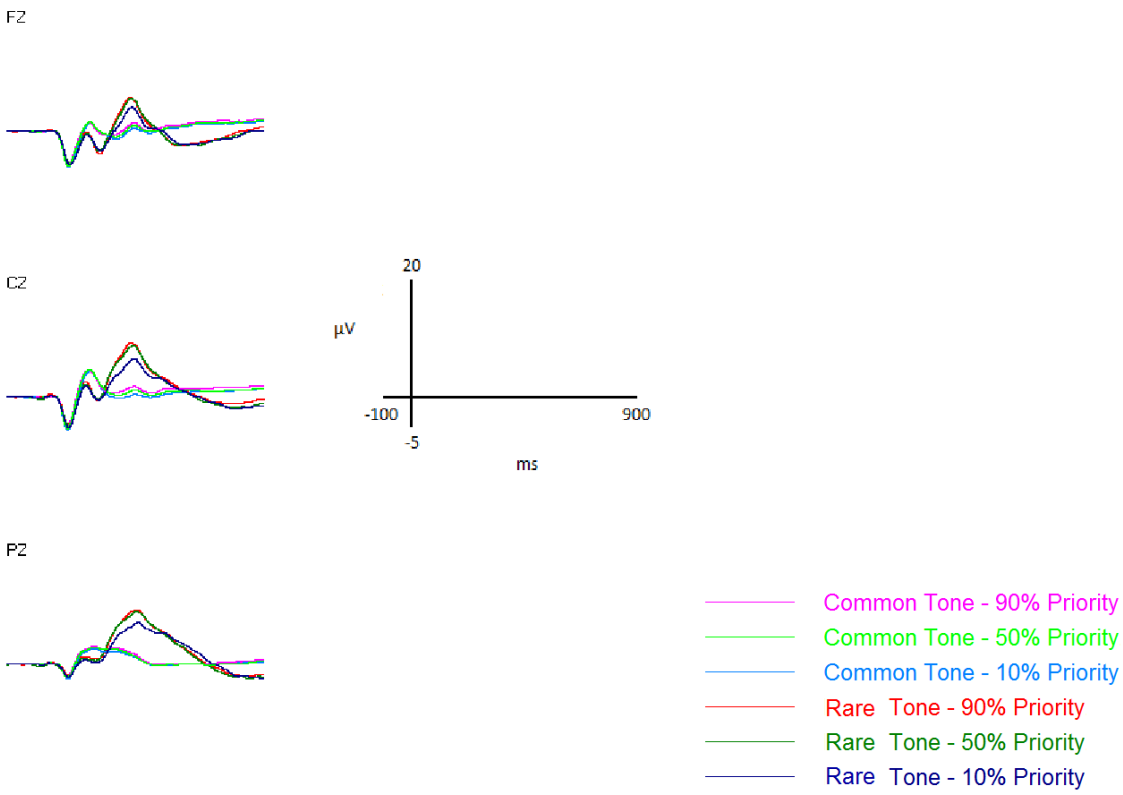

Figure 9.4. Grand mean waveforms for common and rare tones at each level of priority.

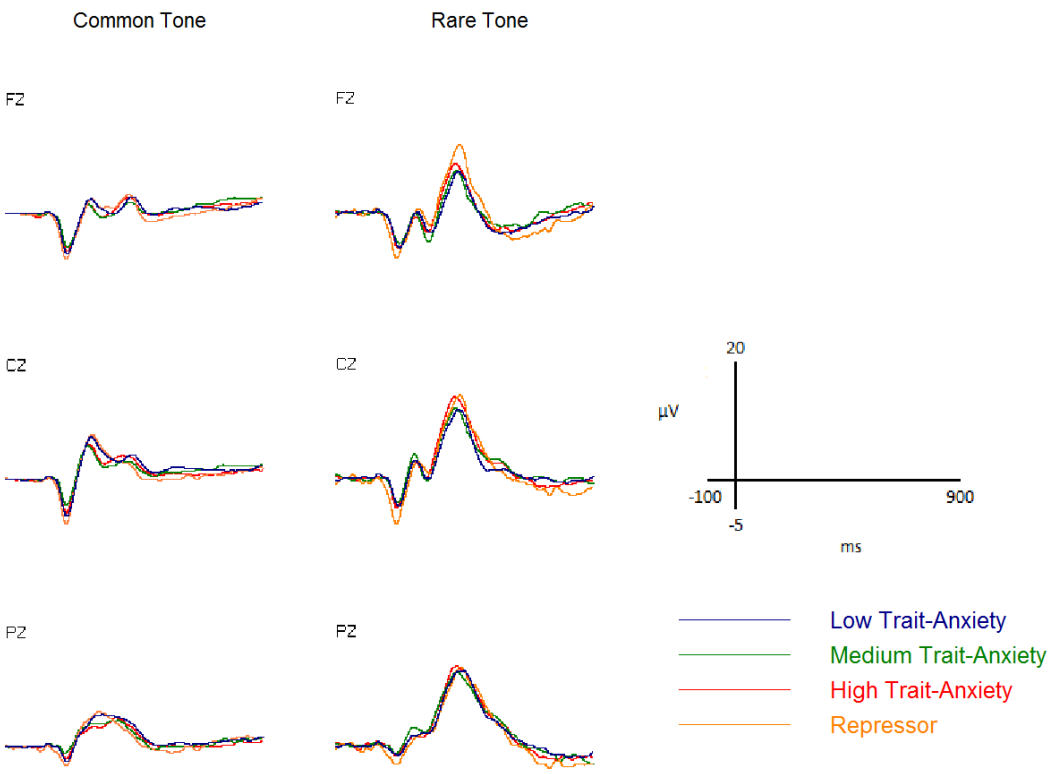

Figure 9.5. Grand mean waveforms for common tones and rare tones for each of the four groups.

Raw data were participants' EEG to Rare tones that were responded to correctly. These were processed as described in the Method section of the current chapter. Each participant's peak amplitude (µV) and latency (ms) for the N1, P2, N2 and P3 components were initially subjected to either, repeated measures ANOVAs with Huynh-Feldt correction to degrees of freedom where appropriate, or one-way between-groups ANOVA, according to dictates of the design. Single-task analyses varied by component according to the maximas identified earlier. Both N1 and P3 underwent 4x2 (Sagittal) mixed ANOVA, whereas P2 and N2 were analysed by one-way between-groups ANOVA. For dual-task analyses, whereas each of the four components underwent initial 4x3 (Priority %) x2 (Difficulty) mixed ANOVA, the N1 and P3 analyses included an additional factor of x2 (Sagittal). Tukey's HSD test was used to evaluate the significance

of differences underlying main effects and interactions between factors, where necessary. Effects were considered statistically significant at, or below, p=.05.

As mentioned earlier, in the interests of focus and brevity only effects of theoretical significance to the present study were reported. As such, the reporting of ERP results was largely constrained to group effects. Whereas all main effects for group were reported, interactions involving group were reported only when these achieved or approached statistical significance.

N1 Amplitude

Single-Task

The initial Group x Sagittal mixed ANOVA indicated the main effect for Group was not significant, $F(3,51)=0.98$, MSE=23.46, p=.411; nor was Group found to interact significantly with Sagittal.

Dual-Task

The initial Group x Priority x Difficulty x Sagittal mixed ANOVA indicated the main effect for Group as trending toward significance, $F(3,51)=2.28$, MSE=95.31, p=.090, η^2=.118. Further, the Group x Difficulty interaction also trended toward significance, $F(3,51)=2.42$, MSE=12.94, p=.077, η^2=.124. Whereas post-hoc analysis indicated no significant simple effects, the graph of the interaction presented as Figure 9.6 provides some indication of the differences likely to have driven the significant interaction. Overall, the Medium Trait-Anxiety group appeared to produce lower N1 amplitude than all other groups, particularly in comparison to the Low Trait-Anxiety group, and lesser so to the High Trait-Anxiety group.

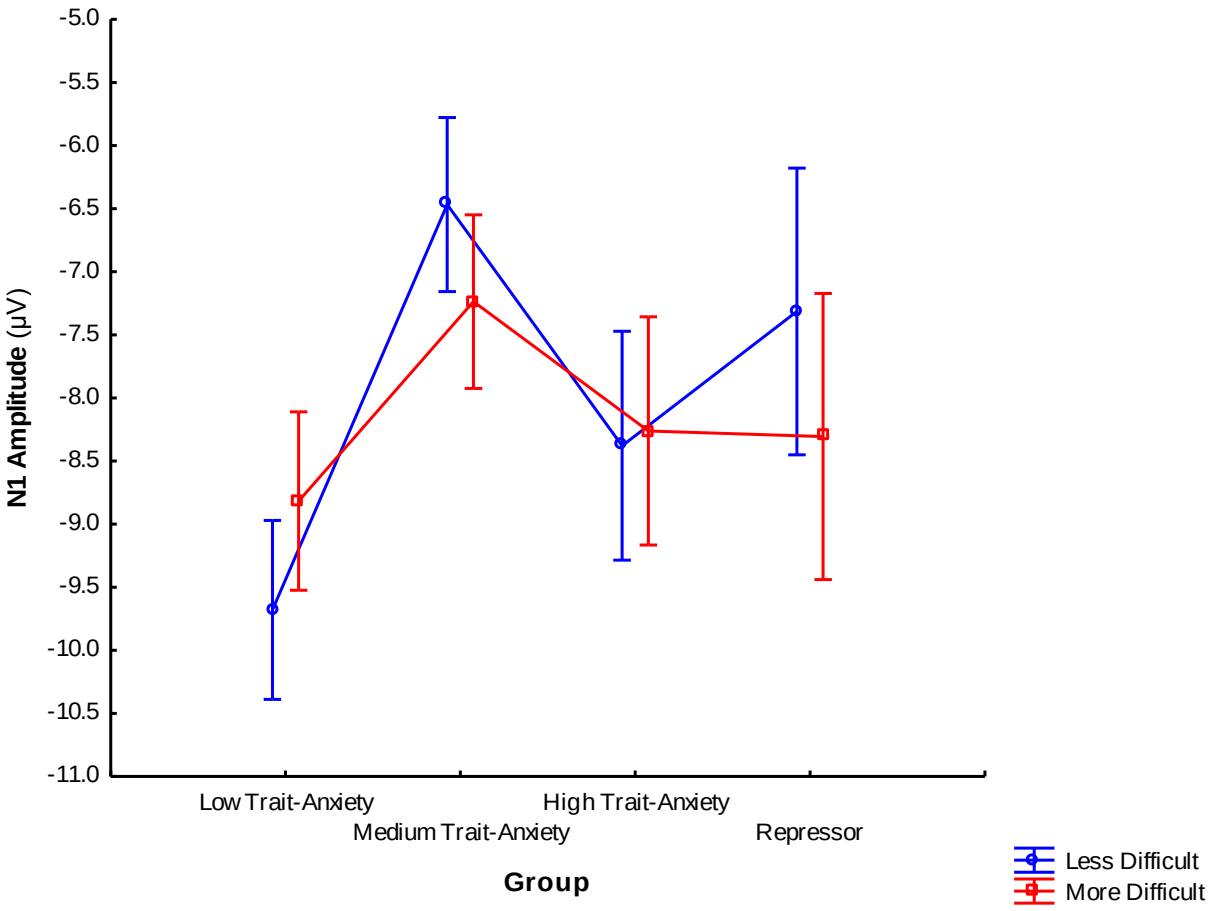

Figure 9.6. N1 Amplitude to Rare tones from the easy and difficult conditions for each of the four groups, for all priority conditions, across Fz and Cz (vertical bars denote SEM).

N1 Latency

Single-Task

The initial Group x Sagittal mixed ANOVA indicated the main effect for Group was not significant, $F(3,51)=0.89$, MSE=281.00, $p=.452$; nor was Group found to interact significantly with Sagittal.

Dual-Task

The initial Group x Priority x Difficulty x Sagittal mixed ANOVA indicated the main effect for Group did not reach significance, $F(3,51)=0.52$, MSE=602.00, $p=.672$; nor was Group found to interact significantly with any other factors.

P2 Amplitude

Single-Task

The one-way between-groups ANOVA at Cz indicated the main effect for Group was not significant, $F(3,51)=0.10$, MSE=19.43, $p=.961$.

Dual-Task

The initial Group x Priority x Difficulty mixed ANOVA at Cz indicated the main effect for Group did not reach significance, $F(3,51)=1.58$, MSE=58.21, $p=.207$. Nor was Group found to interact significantly with any other factors.

P2 Latency

Single-Task

The one-way between-groups ANOVA at Cz indicated the main effect for Group was not significant, $F(3,51)=0.34$, MSE=373.00, $p=.799$.

Dual-Task

The initial Group x Priority x Difficulty mixed ANOVA at Cz indicated the main effect for Group trended toward significance, $F(3,51)=2.25$, MSE=1046.00, $p=.094$, $\eta^2=.117$. Whereas mean P2 latency showed a modest increment from the Low (M=203.70, SEM=3.11) and Medium (M=202.86, SEM=3.03) Trait-Anxiety Groups, to the High Trait-Anxiety Group (M=207.47, SEM=3.98), this became quite marked in relation to the Repressor group (M=217.14, SEM=4.99), which appeared much later. Group was not found to interact significantly with any other factors.

N2 Amplitude

Single-Task

The one-way between-groups ANOVA at Fz indicated the main effect for Group did not achieve significance, $F(3,51)=1.01$, MSE=22.40, $p=.397$.

Dual-Task

The initial Group x Priority x Difficulty mixed ANOVA at Fz indicated the main effect for Group was not significant, $F(3,51)=1.55$, MSE=91.46, $p=.212$. Nor was Group found to interact significantly with any other factors.

N2 Latency

Single-Task

The one-way between-groups ANOVA at Fz indicated the main effect for Group to be non-significant, $F(3,51)=0.63$, MSE=322.00, $p=.596$.

Dual-Task

The initial Group x Priority x Difficulty mixed ANOVA at Fz indicated the main effect for Group not to be significant, $F(3,51)=1.25$, MSE=990.00, $p=.303$. Group was found to trend toward interacting significantly with Priority, $F(5.68,96.54)=1.93$, MSE=133.00, $p=.087$, $\eta^2=.093$; however, this was subsumed by the further trend for the Group x Priority x Difficulty interaction, $F(5.84,99.23)=2.17$, MSE=135.00, $p=.054$, $\eta^2=0.111$. In lieu of any significant post-hoc tests, inspection of Figure 9.7 shows a general tendency whereby N2 appeared to peak later as a function of both trait-anxiety, and reduced priority. The most salient exceptions to this were provided by the Repressor group when performing against the more difficult visual task within the 10% priority to auditory task condition. Surprisingly, the Repressor group appeared to respond with much greater speed to the secondary auditory task when the primary visual task was more difficult than when it was less difficult.

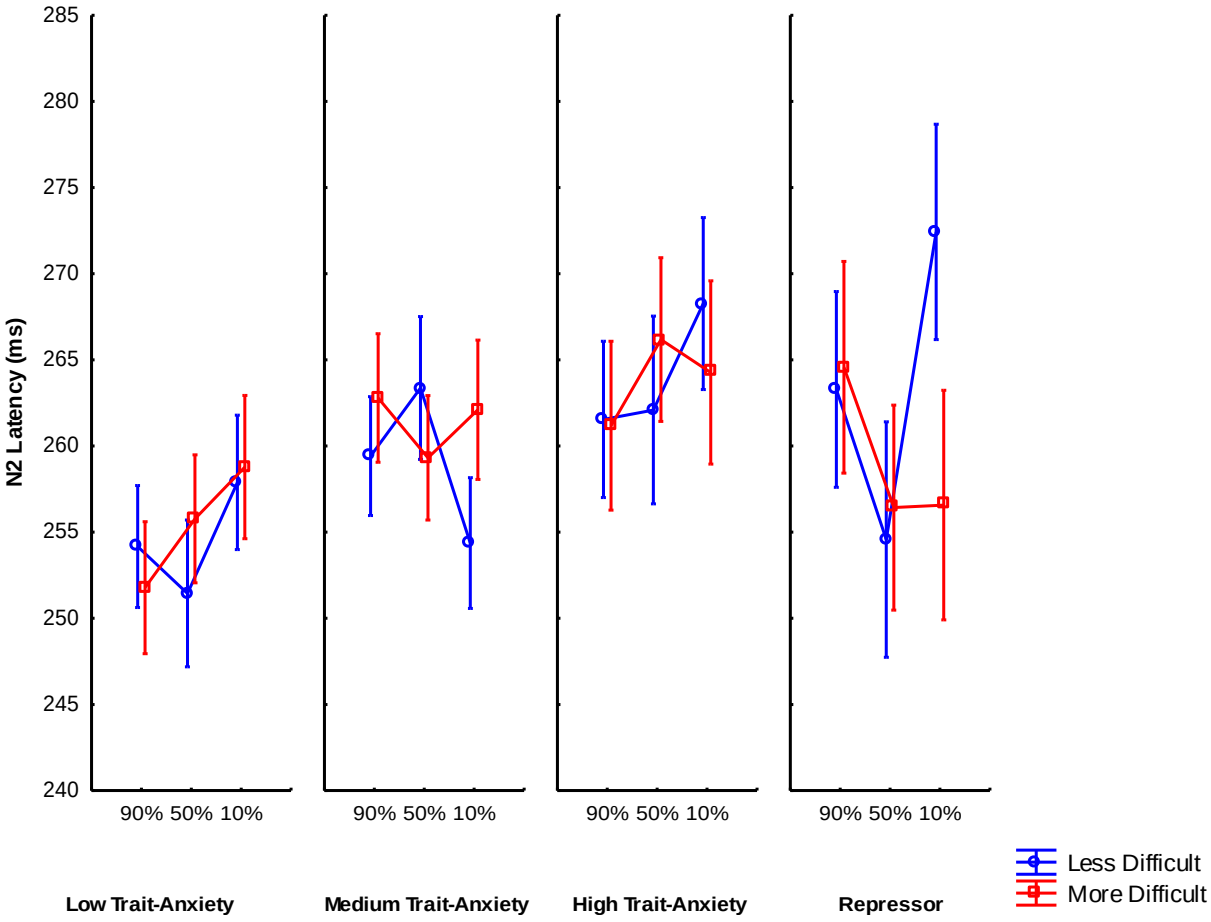

Figure 9.7. N2 latency at Fz for each of the three priority conditions, and both difficulty conditions, for each of the four groups (vertical bars denote SEM).

P3 Amplitude

Single-Task

The initial Group x Sagittal mixed ANOVA indicated the main effect for Group was not significant, $F(3,51)=0.56$, MSE=116.52, $p=.642$. Further, Group was shown not to interact significantly with Sagittal, $F(3,51)=0.64$, MSE=9.39, $p=.596$.

Dual-Task

The initial Group x Priority x Difficulty x Sagittal mixed ANOVA indicated the main effect for Group did not reach significance, $F(3,51)=0.20$, MSE=311.70, $p=.899$; nor was Group found to interact significantly with any other factors.

P3 Latency

Single-Task

The initial Group x Sagittal mixed ANOVA indicated the main effect for Group was not significant, $F(3,51)=0.06$, MSE=2049.00, $p=.979$. Nor was Group shown to interact significantly with Sagittal, $F(3,51)=0.19$, MSE=327.00, $p=.904$.

Dual-Task

Whereas the initial Group x Priority x Difficulty x Sagittal mixed ANOVA indicated the main effect for Group did not reach significance, $F(3,51)=0.92$, MSE=12902.00, $p=.439$; Group was found to interact significantly with Priority, $F(1,51)=3.15$, MSE=1839.00, $p=.007$, $\eta^2=0.137$. As can be seen in Figure 9.8, the Low, Medium and high Trait-Anxiety groups showed little variation in P3 latency, regardless of Priority condition. Whereas the Repressor group showed similar peak latency to each of the other groups within the 90% priority condition ($M=379.93$, $SEM=12.37$), the P3 produced by this group appeared to peak markedly later within the 50% ($M=417.93$, $SEM=14.44$) and 10% ($M=432.43$, $SEM=15.19$) Priority conditions. Indeed, post-hoc tests indicated that, relative to P3 produced by the Repressor group within the 90% condition, those produced within the 10% condition were significantly later ($p<.001$), whereas those produced within the 50% condition only approached significance ($p=.055$). Group was not found to interact significantly with any other factors, nor were any other effects of interest found to be significant.

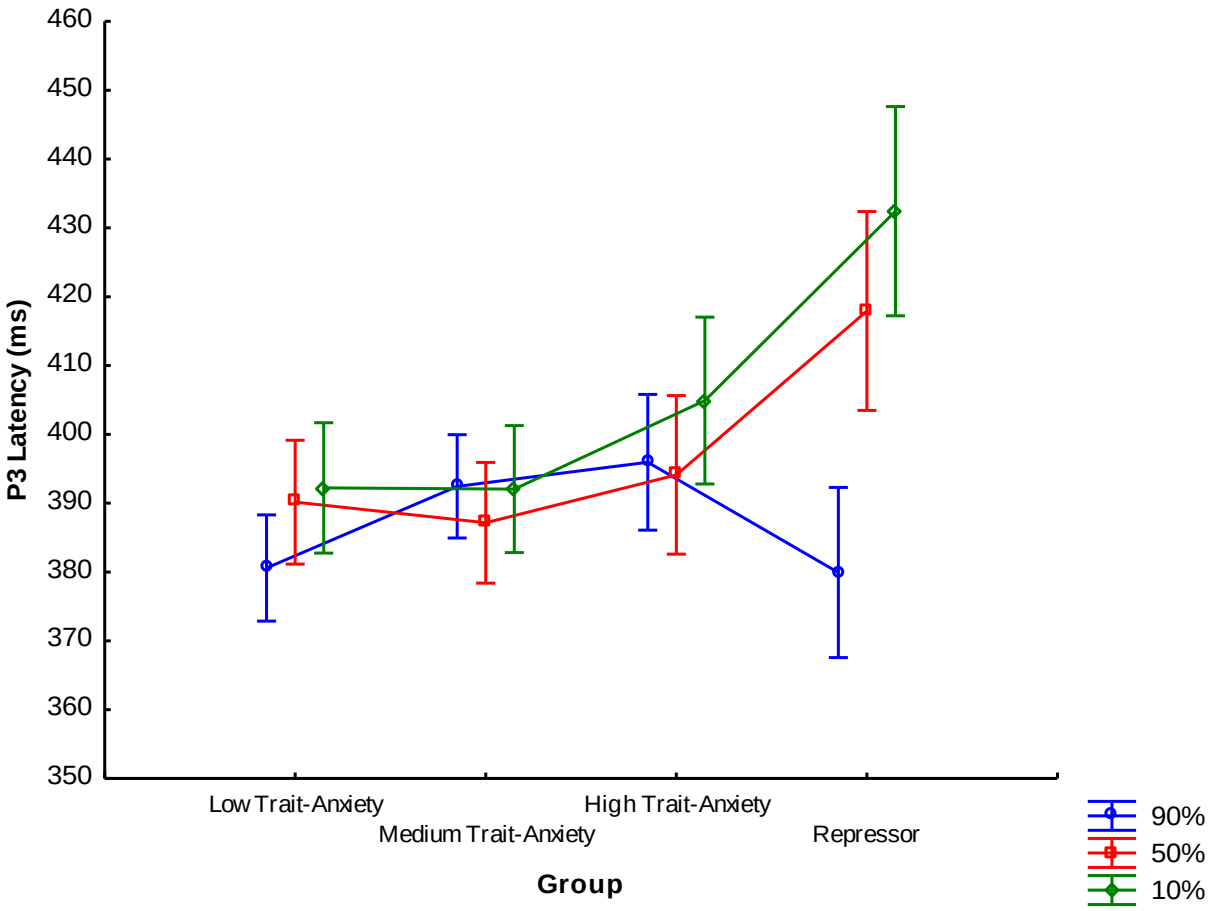

Figure 9.8. P3 latency across Pz and Cz for each of the three priority conditions, for each of the four groups, collapsed across the difficulty condition (vertical bars denote SEM).

Discussion

The aim of the present experiment was to use dual-task processing to investigate potential differences in operational attention between individuals classified as either low trait-anxious, medium trait-anxious, high trait-anxious, or repressors, in an emotionally neutral context. More specifically, the interest was in investigating characteristic management of attentional processing at load; particularly in relation to the number of discrete stimuli in the primary task. In addition to measures of response time and

accuracy, ERPs were employed to provide metrics of the timing and intensity of neural activity associated with cognitive resource allocation during task processing.

Performance Effects

Visual Task

The results of the present experiment provided support for each of the hypotheses. The effect for increased response latency to the more difficult task (tracking eight stimuli), relative to the less difficult task (tracking four stimuli) was significant within both the single-task and dual-task conditions. The main effect for priority was also significant, as were the tests of simple effects which showed that response latency increased for every decrement in priority. As expected, no effects involving group were found to be significant.

Similar to the results for response latency, those for response accuracy provided almost complete support for each of the hypotheses. The effect for decreased response accuracy to the more difficult task, relative to the less difficult task was significant within both the single-task and dual-task conditions. The main effect for priority was also significant. The tests of simple effects showed that, whereas response accuracy was lower within the 10% priority condition than both the 50% and 90% conditions, the latter two did not differ. As expected, no group effects were found to be significant.

Auditory Task

As was the case for the visual task, the results for the auditory task provided almost complete support for each of the hypotheses. Regarding response latency, rare tones were responded to significantly later than common tones within both the single-task and dual-task conditions. The main effect for priority was also significant; however, tests of simple effects showed response accuracy was lower only within the 10% priority condition relative to the 50% and 90% conditions, whereas the latter did not differ. Somewhat contrary to expectations, the group x difficulty x priority interaction trended toward significance (p=.059). Whereas none of the tests of simple effects approached significance, the graph of the interaction (see Figure 9.1) shows that the high trait-anxiety and repressor groups tended to respond later than the low and medium trait-

anxiety groups across the 50% and 10% priority conditions. While this pattern was not statistically significant, the trend is consistent with the global hypothesis proposed for ERP effects, whereby group effects would be more likely under conditions of higher attentional load. In addition, the trend is consistent with observations from the studies presented in Chapters 7 and 8, where apparent interference occurred as a function of latent-anxiety. Further, these observations are consistent with the proposition that anxiety impairs attentional control regardless of the presence of threat-related related stimuli (Derakshan et al., 2009; Eysenck et al., 2007).

Response accuracy to rare tones was shown to be significantly lower than common tones within single-task and dual-task conditions; however, within the single-task the main effect was modified by a significant interaction with group. Post-hoc tests confirmed the source of this interaction was markedly lower accuracy to rare tones by the repressor group. Whereas this difference did not quite reach significance relative to the medium trait-anxiety group, the effect is relatively clear; however, accounting for this may not be so straightforward.

One possible explanation involves the proposition discussed in Chapter 5, whereby repressors may buffer conscious experience of anxiety is through an opposite interpretive bias (e.g., Eysenck, 1997; Calvo & Eysenck, 2000). In the present experiment, it is likely that under the relatively low processing load of the single auditory task, participants would be heavily primed by the anticipation of the fixed interval tones. Hence, response activation thresholds would likely be lower; resulting in weaker information resolution. If repressors possess an enhanced capacity for interpretive bias, then it is not unlikely that this may have combined with the active response-set from the previous trials to effect sufficient interference to affect performance in the manner observed, presently. This explanation notwithstanding, it is clear that the repressor group experienced some interference in processing at this relatively low processing load.

Returning to the dual-task condition, the main effect of difficulty did not reach significance, indicating that the difficulty level of the visual task did not impact the speed of responses to the auditory task. The main effect for priority was found to be significant. The tests of simple effects showed response accuracy was lower within the

10% priority condition than both the 50% and 90% conditions, whereas the latter conditions did not differ.

ERP Data

The ERP results showed only four effects involving group approached significance. The trend (p=.077) toward significance for the group x difficulty interaction for N1 amplitude did not show the expected positive relationship with latent-anxiety. Indeed, the low trait-anxiety group appeared to produce greater N1 amplitude relative to each of the other three groups.

There was a very weak trend (p=.094) toward significance for the main effect of group for P2 latency, whereby this increased as a function of latent trait-anxiety. The tentatively predicted increase in N2 amplitude as a function of latent-anxiety was not found. Nevertheless, there was a strong trend (p=.054) toward significance for the group x priority x difficutly interaction for N2 latency, which overall, showed a tendency to increase as a function of latent-anxiety.

The only effect to achieve significance was the group x priority interaction for P3 latency. Tests of the simple effects showed that, the low, medium and high trait-anxiety groups showed little variation in P3 latency, regardless of Priority condition. Whereas the repressor group showed similar peak latency to each of the other groups within the 90% priority condition, P3 produced by the repressor group within the 50% and 10% peaked significantly later. Given this, it may be suggested that the repressor group were singularly adversely affected by instruction to reduce attentional priority. Perhaps the repressor group was the only group to successfully vary attention according to instruction, or perhaps they were less capable of modulating attentional allocation. This is moot, due to the lack of associated effects that would provide context by which to evaluate this. Whatever the case, the lack of concomitant effects for response latency or accuracy within the dual-task condition indicates that behavioural performance was not affected by the production of P3, which is commonly considered to index attentional resource activation associated with decision making processes (Donchin, 1981; Hillyard & Kutas, 1983; Johnson, 1986; Kok, 1997, 2001; Polich, 2007; Verleger et al., 2005).

Summary and Conclusion

The aim of the present study was to investigate the prospect of differential management of attentional resources allocation under the demands of single-task and dual-task processing by individuals classified as either low trait-anxious, medium trait-anxious, high trait-anxious, or repressors, in an emotionally neutral context. As predicted, the results of the behavioural measures of response time and accuracy provided compelling evidence of the success of the difficulty and priority manipulations. In addition, there was clear evidence that the repressor group responded with relatively poor accuracy to rare auditory events. In the absence of a compelling account for this effect, it was clear that the repressor group experienced some interference in processing at this relatively low processing load.

The ERP results were largely insensitive to group effects. On the basis of the effects observed in Chapters 7 and 8, it was anticipated that the amplitude and latency of N1, and the amplitude of N2 would increase as a function of latent-anxiety. Whereas these effects were not found, there was some evidence of P2 and N2 latency increasing as a function of latent-anxiety, by way of broad trends. Indeed, the only effect to achieve significance was the group x priority interaction for P3 latency, which indicated that the repressor group was singularly adversely affected by instruction to reduce attentional priority.

To conclude, the behavioural results of the present study showed that difficulty and priority manipulations were successful in effecting increases in attentional load. Despite this, only two group effects were found to be significant. Neither of these was consistent with expectations arising from theory or the results from the studies reported in Chapters 7 and 8. Nevertheless, the fact that both of these related to the repressor group deviating from the low, medium and high trait-anxiety groups lends some support to the divergent validity of this group in relation to the low and high trait-anxiety groups.

Chapter 10: General Discussion

The aim of the present dissertation was to investigate whether the operation of selective attention differs in people according to variation in latent trait-anxiety in conditions that are ostensibly absent of emotional valence. Different personality styles entail different cognitive processing styles, and there is strong evidence of variation in the psychological management of information interpretable as signifying potential threat. Individuals with high levels of trait-anxiety have been shown to have an attentional bias for threatening stimuli or events. This appears more related to a relative difficulty with disengaging attention from sources of potential threat, rather than a greater attraction to it, per se. Individuals low in trait-anxiety do not exhibit such a bias. There is also evidence that high trait-anxiety impairs attentional control regardless of the presence of threat-related or task-irrelevant stimuli. This can be explained in terms of an adaptive mechanism inhibiting strong attentional fixation on anything under circumstances where a person perceives themselves to be under threat. This suggests that individuals with high trait-anxiety may have a relative deficiency in attentional control (for reviews, see: Eysenck, 1992; Mathews & MacLeod, 1994; Williams et al., 1996).

Given the robust findings of a particularly detrimental effect of threat-perception on processing efficiency in high trait-anxiety, the development of functional compensatory strategies would appear adaptive. A third group, who report low trait anxiety, but show high anxious reactivity, have been identified as employing a repressive coping style. The prospective flexibility of preconscious selective attentional processes provides opportunity for the suppression from consciousness of threat-related information thought to operate in repression. The two primary tenets of repressive coping style are that repressors show biases indicating that they are avoidant of threatening material, and that these avoidant processes are found with both external and internal stimuli (for reviews, see: Derakshan et al., 2007; Schwerdtfeger & Kohlmann, 2004; and Weinberger, 1990).

The evidence suggests that repressors engage in a vigilance-avoidance style of appraisal. Here, it appears that stimuli and events are pre-attentively scanned for sources of potential threat, which are then quarantined from conscious experience. The capacity for individuals to repress their experience of anxiety in this way has implications for the

understanding of selective attentional processes. It suggests the operation of a process where the emotional significance is evaluated pre-attentively with stimuli deemed emotionally significant given priority, or not, in the competition for access to selective attention.

The evidence-based theory for both repressive coping style and trait-anxiety is dominated by the theme of a sequential stage model involving preconscious appraisal of information toward selection for conscious management. Repressors and high trait-anxious individuals appear to differ in the strategic operations undertaken to conduct these processes. Repressors show a tendency to attenuate and dismiss potentially threatening information, whereas high trait-anxious individuals show a tendency for amplification and focus.

Attentional Control Theory (Eysenck et al., 2007) included the proposal that the effects of latent-anxiety are likely to impair processing efficiency more than performance effectiveness. Further, this theory posits that latent trait-anxiety affects attentional control regardless of the presence of ostensible threat. To date, two studies have provided evidence in support of this proposal. Both of these studies showed impaired performance by high trait-anxious on spatial-orienting paradigms that were independent of ostensible threat (Derakshan et al., 2009; Derryberry & Reed, 2002; as discussed in Chapter 5).

Whereas these findings provide support for the position that the early attentional processing strategies associated with high trait-anxiety operate independent of threat, such evidence has remained wanting in the case of repression. Hence, the primary objective of the present thesis was to investigate operational variability between individuals according to trait-anxiety or repressor status, within emotion-neutral contexts. Whereas several theories were drawn upon throughout this dissertation, it was not the aim of the present thesis to test any of these, per se. As stated earlier, the aim of the present dissertation was to investigate whether the operation of selective attention differs in people according to variation in latent trait-anxiety in conditions that are ostensibly absent of emotional valence.

This investigation comprised three studies, each of which employed performance measures of response time and response accuracy. In addition, ERPs were employed as

an index of subtle differences in the allocation of attentional resources. Participants were females aged between 17 and 34 years, with no history of mood disorder, who were classified as either low trait-anxious, medium trait-anxious, high trait-anxious, or repressors according to their STAI-T and MCSDS scores. The experimental paradigms employed with the three studies were selected for their ability to allow observation of component processes of selective attention. These were based on the mechanisms of disengagement, shifting and engagement described by Posner and Petersen (1990), which remains the leading model of the mechanisms of selective attention (Yiend, 2010).

The primary focus of the Stroop-interference experiment, presented in Chapter 7, was to investigate the inhibition of attention as a function of the disengagement sub-component of selective attention. An additional aim of that experiment was to perform a study of ERP correlates of Stroop colour-word interference. The behavioural performance data confirmed the achievement of a strong classic Stroop-interference effect, but did not show any group effects. Whereas the P3 and P2 components were found to be sensitive to Stroop interference in both the amplitude and latency dimensions, these effects were independent of group. Evidence of differential processing across groups was found on both the N2 and N1 dependent measures. The effect whereby N2 amplitude increased as a function of latent trait-anxiety provided support for the proposal of Eysenck et al. (2007) that anxiety has an adverse affect on processing efficiency in the absence of threat context. The latency of N1 also increased as a function of latent anxiety. Taken together, the effects observed across N1 and N2 suggests a pattern of processing whereby engagement of cognitive resources associated with selective-attentional processing tended to increase with latent trait-anxiety. There was, however, no evidence of a later-stage processing advantage by the repressor group. Hence, these results were not entirely consistent with the operation of a two-stage vigilance-avoidance attentional mechanism in repression, as proposed by Derakshan et al. (2007).

The second study, presented in Chapter 8, employed a local-global Stroop-task embedded within a task-switching methodology toward investigating the degrees of operational flexibility possessed by the experimental groups on the subcomponents of

selective attention. The task-switching methodology used comprised a combination of alternating-runs and task-cueing paradigms to examine top-down and bottom-up influences occurring within task-set reconfiguration and task-set inertia, respectively.

The strength and consistency of the effects observed for response latency and accuracy provided unequivocal support for the validity of the task-switching methodology employed in the present study. The single group effect for the performance measures involved the repressor group achieving greater accuracy on the global task within the task-cueing paradigm compared to the alternating-runs paradigm. This effect showed strong concordance with that observed for N1 latency, whereby processing by repressors was differentially affected by the task-cue and local-global interference.

The majority of ERP findings involving group differences were consistent with both Attentional Control Theory (Eysenck et al., 2007) and Vigilance-Avoidance Theory (Derakshan et al., 2007). Indeed, the N1, P2 and N2 components all showed a pattern whereby amplitudes increased (for N2 and N1), or decreased (for P2) as a function of latent anxiety. The first evidence of deviation from this appeared on N2 latency, where the high trait-anxiety group showed a clear tendency to peak latest, whereas the other three groups showed quite similar latencies. Taken together with the results for N2 amplitude, it appears that the repressor group effected greater processing speed and intensity than the low trait-anxiety group. The proposal that this may represent the beginnings of divergence from the pattern whereby effects have tended to correspond with latent anxiety was supported by the P3 amplitude data. Whereas the P3 amplitude produced by the repressor group did not quite show processing equivalent to that of the low and medium trait-anxiety groups, it did appear less affected by the demands on processing resources relative to the high trait-anxiety group.

Overall, the convergent evidence from the task-switching study showed concurrence with the two-stage model of attentional processing in repression proposed in Vigilance-Avoidance Theory (Derakshan et al., 2007). The primarily exogenous N1 and P2 components clearly represented the less-controlled ‘vigilance’ stage, with the principally endogenous P3 component representing the more-controlled ‘avoidance’ stage. Whereas the N2 component appeared heavily influenced by bottom-up interference, there was also evidence of top-down influence over attentional processing strategy. This may

constitute evidence of the proposed flexibility of selective attentional control by repressors.

The stable pattern for early attentional processing to vary as a function of latent anxiety provided strong evidence for the divergent validity of the construct of repressive coping style. The typically observed significant differences between the amplitudes produced by the repressor and low trait-anxiety groups distinguish these as sub-groups of people who report low trait-anxiety. Further, the stable tendency for the repressor group to exceed the processing extremity of the high trait-anxiety group suggests these groups did not engage in equivalent processing. Indeed, the results indicated that the repressor group were more susceptible to interference from extraneous information. Whereas these findings were not always supported by strong effects, the observation of these in threat-absent conditions within a lengthy experimental session suggests the existence of a characteristic processing style that operates independently of perceived threat.

A particularly interesting, and potentially important finding from the task-switching study was the effect whereby the repressor group appeared to be singularly affected by the local-global elements of the stimuli when conducting N1-related processing. Further, the coherent pattern associated with this was consistent with the proposition that repressors may possess a bias toward enhanced attention to discrete elements; and that such a bias may reflect a propensity for compartmentalised processing of information that might be considered characteristic of repressors.

The final study, presented in Chapter 9, was conducted to both investigate the prospect that repressors may possess a characteristic bias for enhanced attention to the discrete stimuli, and elucidate the relationship between the low trait-anxiety and repressor groups on later-stage attentional processing. The use of single-task and dual-task paradigms allowed for a reduction in the complexity of task processing, while still allowing for an increase in the number of stimulus events to be simultaneously processed.

The results of the behavioural measures of response time and accuracy provided compelling evidence of the success of the difficulty and priority manipulations. A curious effect was observed, whereby the repressor group responded with relatively poor

accuracy to novel auditory events under the relatively low-demand single-task processing. This was considered to reflect the effect of interference, possibly associated with anticipatory priming and task-set inertia. There was a surprising lack of ERP effects involving group, with the solitary significant result indicating that the repressor group were singularly adversely affected by instruction to reduce attentional priority.

The lack of effects expected for N1 and N2 from the final study notwithstanding, when taken together, the findings from the studies presented within the present thesis represent a reasonably consistent profile of effects with regard to the effect of latent trait-anxiety on attentional processing. The results of the Stroop-interference and task-switching studies showed a pattern whereby processing indexed by N1 and N2 increased as a function of latent trait-anxiety. Whereas no evidence was found for a later-stage processing advantage for repressors, the combination of early interference and the observation of P3 in the task-switching study shaping toward consistency with the low trait-anxiety group may modify the null findings for P3 from the Stroop-interference study. That is, in relative terms, the absence of attenuated P3 may represent some form of later-stage advantage when taken in the context of earlier-stage interference as a product of vigilance.

Limitations and Implications

The lack of supportive findings from the dual-task experiment tempers the confidence with which any inferences about the findings from the Stroop-interference and task-switching studies can be made. In addition, whereas the number of observations available from the sample sizes were sufficient to elicit strong effects for the experimental task manipulations, it is likely that low group numbers contributed to the relatively weak group effects. Further, it is likely that the number of ANOVA tests conducted within each experiment has artificially inflated the alpha level of .05, and thereby increased the chance of Type I error. Whereas the application of existing corrections for multiple comparisons was considered, none of these were deemed appropriate. For instance, corrections such as Bonferroni (Dunn, 1961) and Šidák (Šidák, 1967) provide a corrected alpha level of .005 for 10 comparisons. Given the numbers of ANOVA performed in each experiment ranged from 10 in the Stroop

experiment, 18 in the Task-Switching experiment, and 24 in the Dual-Task experiment, such corrections would result in an unacceptable increase in the chance of Type II error. As such, no adjustment was made to address the increased risk of Type I error. Hence, the results reported as significant in the present thesis should be considered with relative caution, particularly those with higher p-values. This notwithstanding, overall, the findings were reasonably consistent across the Stroop-interference and task-switching studies; the profiles of which provided steady support for the legitimacy of the repressor group as independent from both the low and high trait-anxiety groups.

The apparent evidence of the existence of divergent attentional processing by repressors has implications for both future and past research. First, this supports the assertion of Mogg et al. (2000), that research into cognitive models of anxiety should routinely include measures to detect repressors. Indeed, the lack of such screening calls into question the validity of null findings regarding differences between low and high-anxiety groups, as it is likely that repressors were grouped with truly low-anxious participants. On the basis of this, it may be relevant to retest previously discounted relationships.

The current findings also leave, or lay open, a number of questions; for instance, the process by which repressors transition from early-vigilance to later-avoidance remains to be understood. Additionally, whereas additional investigation of the prospect of attentional bias toward discrete events is salient, the investigation of attentional processing by repressors to verbal information would also warrant examination. Further, the prospect of an association between repressive coping style and sub-clinical dissociation may also be worthy of investigation.

Conclusion

To conclude, the convergent evidence from the Stroop-interference and task-switching studies showed reasonable concurrence with both Attentional Control Theory (Eysenck et al., 2007) and the two-stage model of attentional processing in repression proposed in Vigilance-Avoidance Theory (Derakshan et al., 2007). The primarily exogenous N1 and P2 components clearly represented the less-controlled ‘vigilance’ stage, with the principally endogenous P3 component representing the more-controlled

'avoidance' stage. Whereas the N2 component appeared heavily influenced by bottom-up interference, there was also evidence of top-down influence over attentional processing strategy. This may constitute evidence of the proposed flexibility of selective attentional control by repressors. All in all, the findings of the present dissertation support the propositions that repressors represent a distinct sub-group of high trait-anxious people, and that the characteristic attentional processing styles of both of these groups operate independently of ostensible threat.

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Appendix A

Demographic Information Form

Demographic Information

Date: _____

Age in Years _____ Months _____

Sex: Male Female

Is English your first language? Yes No

If English is not your first language, how would you rate your English language skills? Circle one answer only:

A. My English language skills are better than my fist language skills.

B. My English language skills are equal to my first language skills.

C. My English language skills are not as good as my first language skills.

Contact Information

If you would consider participating in further research (for course credit) please provide your contact information as possible below. Providing this information does not obligate you to further participation.

Name: _____

Email address: _____

Phone: Home _____ Mobile _____

Appendix B

Medical and History Questionnaire

[on University letterhead]

General Medical Questionnaire for all studies.

The effects of personality style on cognitive processing

Medical and History Questionnaire[1]

University of Tasmania
School of Psychology

Date...../...../.....

Participant Code.....

Medical History

Are you currently suffering from anxiety or depression?.....

Do you have a heart condition or any other serious physical condition?

.....

Are you currently taking any prescription medication? If so, what medication?

.....

Have in the past taken any medications for psychological condition(s)? If so, what medications?

.....

Is there any possibility that you could be pregnant?

.....

Have you ever had or are you now suffering from any of the following (please circle):

Fits or convulsions	*Yes*	*No*
Epilepsy	*Yes*	*No*
Giddiness	*Yes*	*No*
Concussion	*Yes*	*No*
Severe Head Injury	*Yes*	*No*
Loss of Consciousness	*Yes*	*No*

Drinking and Smoking History

On how many days last week did you drink alcohol?

None
One or two days
Three or four days
Five or six days
Every day

Do you usually drink...	Never During weekdays Friday night Weekends
How many drinks would you usually have at one time?	One or two Three to five Five to eight Eight to twelve More than twelve
Do you get drunk?	Never Rarely Once a month Once a week More frequently
How often do you smoke a cigarette?	Never Less than 5 per week Less than 5 per day 5 to 9 per day 10 to 19 per day 20 to 39 per day Over 40 per day

Do you or have you in the past used marijuana? (please circle)	Yes	No
a) Have you used marijuana in the last two weeks?	Yes	No
b) Have you used any other form of illicit drug in the last 6 months?	Yes	No

Vision

Do you have any difficulties with vision? (please specify)

.....

If yes, are these difficulties corrected (i.e. glasses/contacts)

.....

Hearing

Do you have any difficulties with hearing? (please specify)

.....

If yes, are these difficulties corrected (i.e. hearing aid)

.....

Appendix C

Information Sheet

[on University letterhead]

The effects of personality style on cognitive processing

Dr Frances Martin (Chief Investigator, Senior Lecturer, School of Psychology)
Dallas Hope (Student Investigator, School of Psychology)

Date:

We would like to invite you to participate in a study investigating the effects of personality style on cognitive processing and how these are reflected in levels of brain activity and task performance. This study is being conducted as part of the requirements for a PhD in Psychology for Dallas Hope and will be carried out in the Cognitive Psychophysiology (ERP) Laboratory at the School of Psychology, University of Tasmania (Hobart). Dallas Hope can be contacted at the Cognitive Psychophysiology Laboratory (ERP Laboratory) on phone 6226 2885, or by email: Dallas.Hope@utas.edu.au. Frances Martin can be contacted on 6226 2262 or e-mail: F.Martin@utas.edu.au .

If you decide to participate in this research you will gain experience in research procedures and also knowledge about the relationship between cognitive processes and performance. Although this research will not be applied to a special population or involve any type of therapeutic intervention, it will provide a foundation upon which we can have a better understanding of the mechanisms by which people process cognitive information.

We are looking for volunteers between the ages of 17 and 30. If you are a heavy alcohol drinker, heavy tobacco or cannabis smoker, have a history of, or are currently suffering from, a neurological condition, you should not volunteer for this study. I will ask you to complete a questionnaire about these conditions before the experiment begins. If you are taking any prescription medication, you should let the researcher know.

If you choose to volunteer for this research, you will be asked to complete some simple attention tasks presented on a computer monitor and some questionnaires. While you are performing some of these simple tasks your brain activity and the time it takes you to respond to the stimuli will be recorded. While the equipment used to measure brain activity may feel a little uncomfortable, it is not painful in any way, however if you have sensitive skin, you should inform the researcher. It is possible that you may get fatigued and to alleviate this, frequent rests will be given during the experimental sessions.

All of the individual information collected in this research will be treated confidentially and will be coded to ensure anonymity. Your name will not be noted on any of the data collected. The data will be held in locked cabinets or on password secured computers at the School of Psychology at the University of Tasmania for a period of at least five years (with the exception of the medical questionnaires which will be destroyed on completion of the study). Following completion of the research, the data may be published, however, you will not be personally identifiable in these publications. A summary of the results of these experiments will be available on the University of Tasmania School of Psychology Web page at www.scieng.utas.edu.au/psychol or will be available by contacting the researcher.

Participation in this research is entirely voluntary, and your consent to participate is evidenced by signing a consent form. In any case, you may choose to withdraw from the study at any time without prejudice. If you choose to withdraw from the study, you may also choose to withdraw your data. If you are a student at the University of Tasmania deciding to withdraw from this research at any time will not affect your academic standing in any way. You will be given copies of this information sheet and the statement of informed consent to keep. The researcher will be available after the testing session to answer any questions you may have. If you have any questions, or would like any additional information regarding this research please contact Dr Frances Martin on (03) 6226 2262 or Dallas Hope on (03) 6226 7664.

This research has received ethical approval from the Human Research Ethics (Tasmania) Network. If you have any questions regarding the ethical nature or complaints about the manner in which the study is conducted, you may contact the Executive Officer (Amanda McAully on 03 6226 2763; email: Human.ethics@utas.edu.au).

Dr Frances Martin
(Chief Investigator)

Dallas Hope
(Student Investigator)

Appendix D

Statement of Informed Consent

[on University letterhead]

The effects of personality style on cognitive processing

Dr Frances Martin (Chief Investigator, Senior Lecturer, School of Psychology)
Dallas Hope (Student Investigator, School of Psychology)

Participant Consent Statement:

I have read and understood the *Information Sheet* for this research. The nature and possible effects of the research have been explained to me. Any questions that I have asked have been answered to my satisfaction.

I understand that the research requires me to complete some simple attention tasks presented on a computer monitor and some questionnaires while my brain activity will be recorded. I understand that I will be asked about recreational drug habits, use of prescription medication, and any neurological conditions. I understand that I should indicate to the experimenter if I have sensitive skin and that I should request a rest if I become fatigued.

I understand that all of the individual information collected in this research will be treated confidentially and will be coded to ensure anonymity. I agree that research data gathered for the study may be published provided that I cannot be identified as a participant.

I agree to participate in the investigation and understand that I may withdraw from participation and/or withdraw my data at any time without prejudice to my academic or other standing.

Name of participant.....

Signature of participant.....
Date.....

Investigator Statement

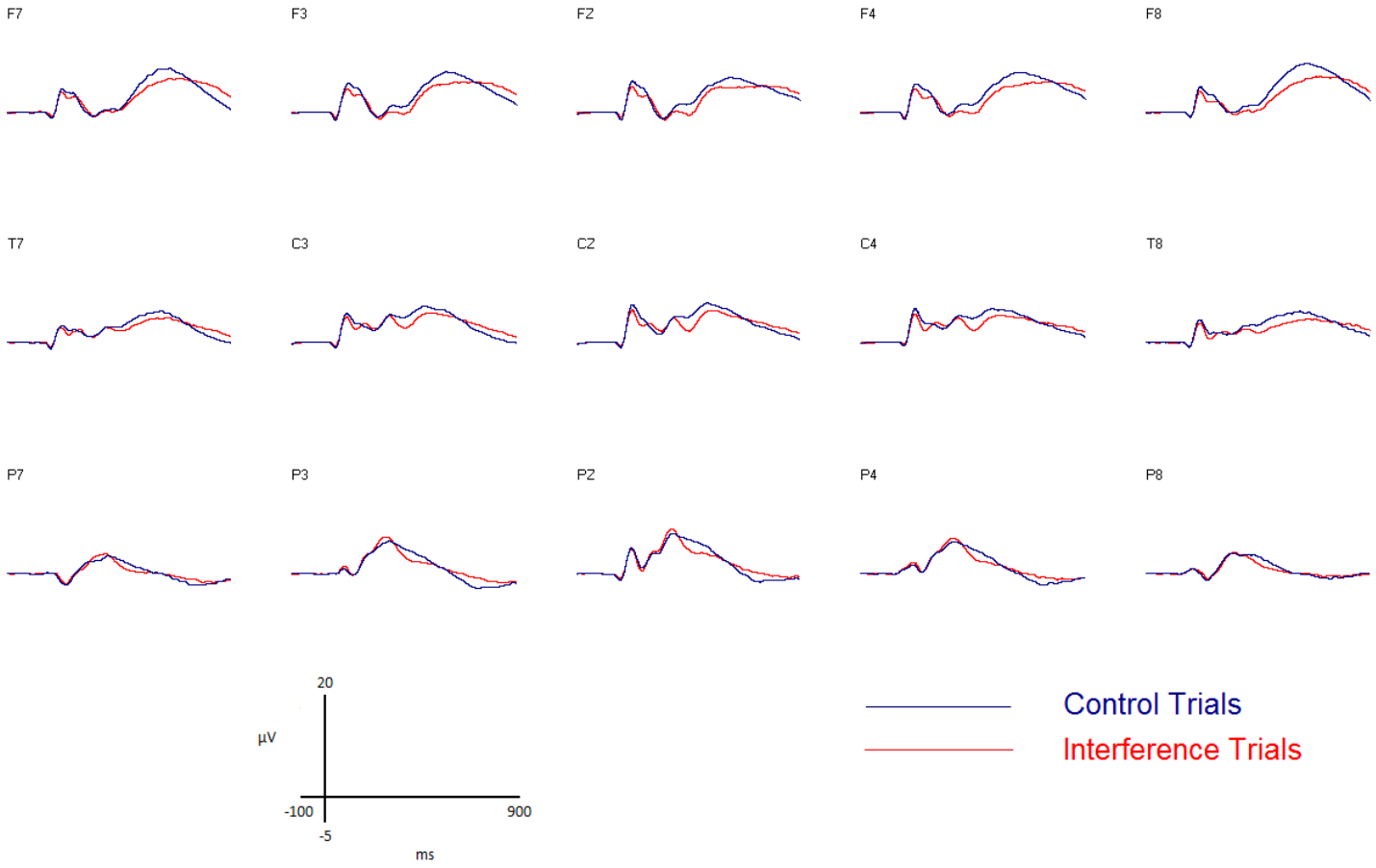
I have explained this research and the implications of participation in it to this volunteer and I believe that the consent is informed and that he/she understands the implications of participation.

Name of investigator.....

Signature of investigator.....
Date.....

Appendix E

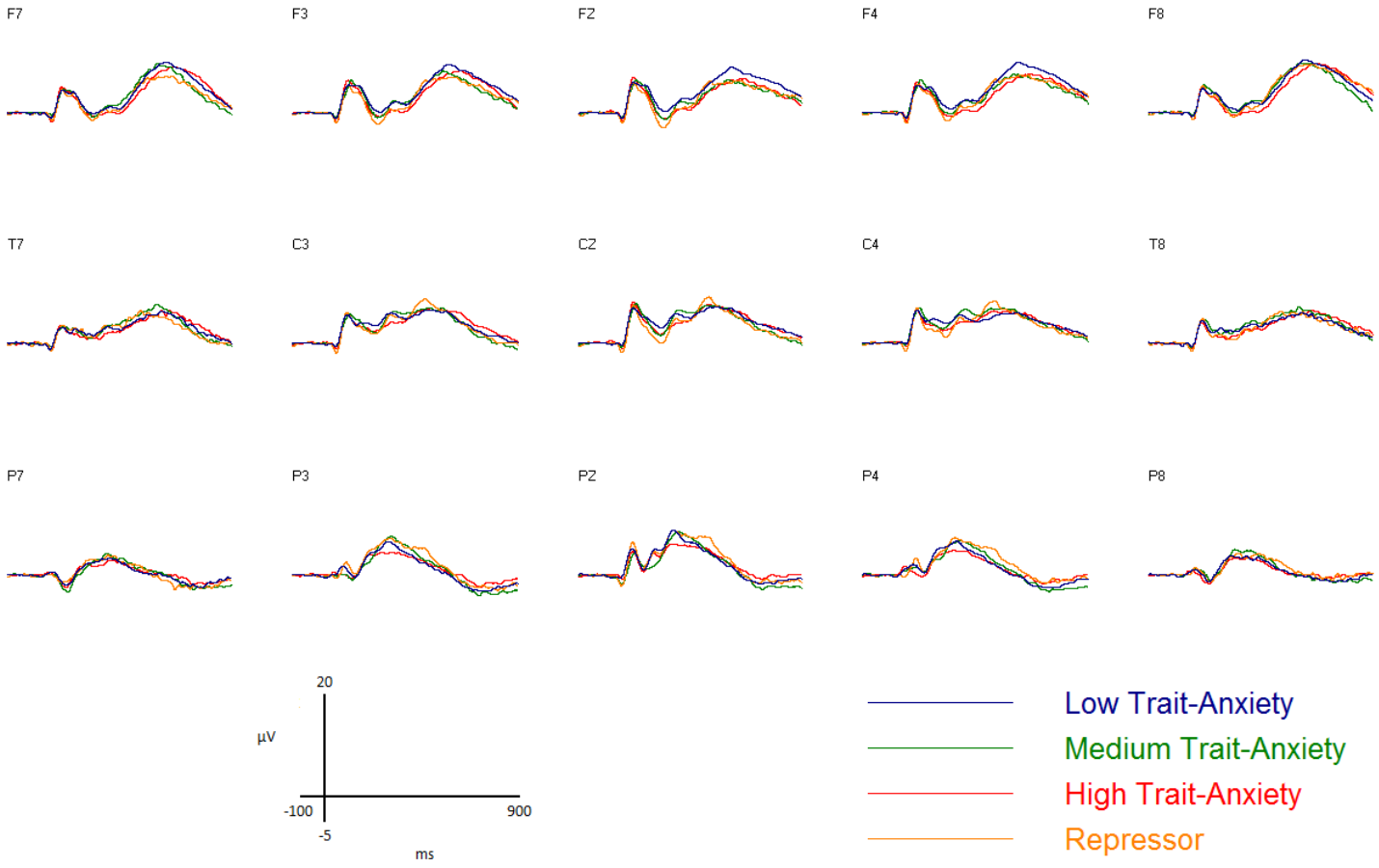
Full array of grand mean waveforms for interference and control trials (refer Figure 7.1)



Full array of grand mean waveforms for interference and control trials (refer Figure 7.1).

Appendix F

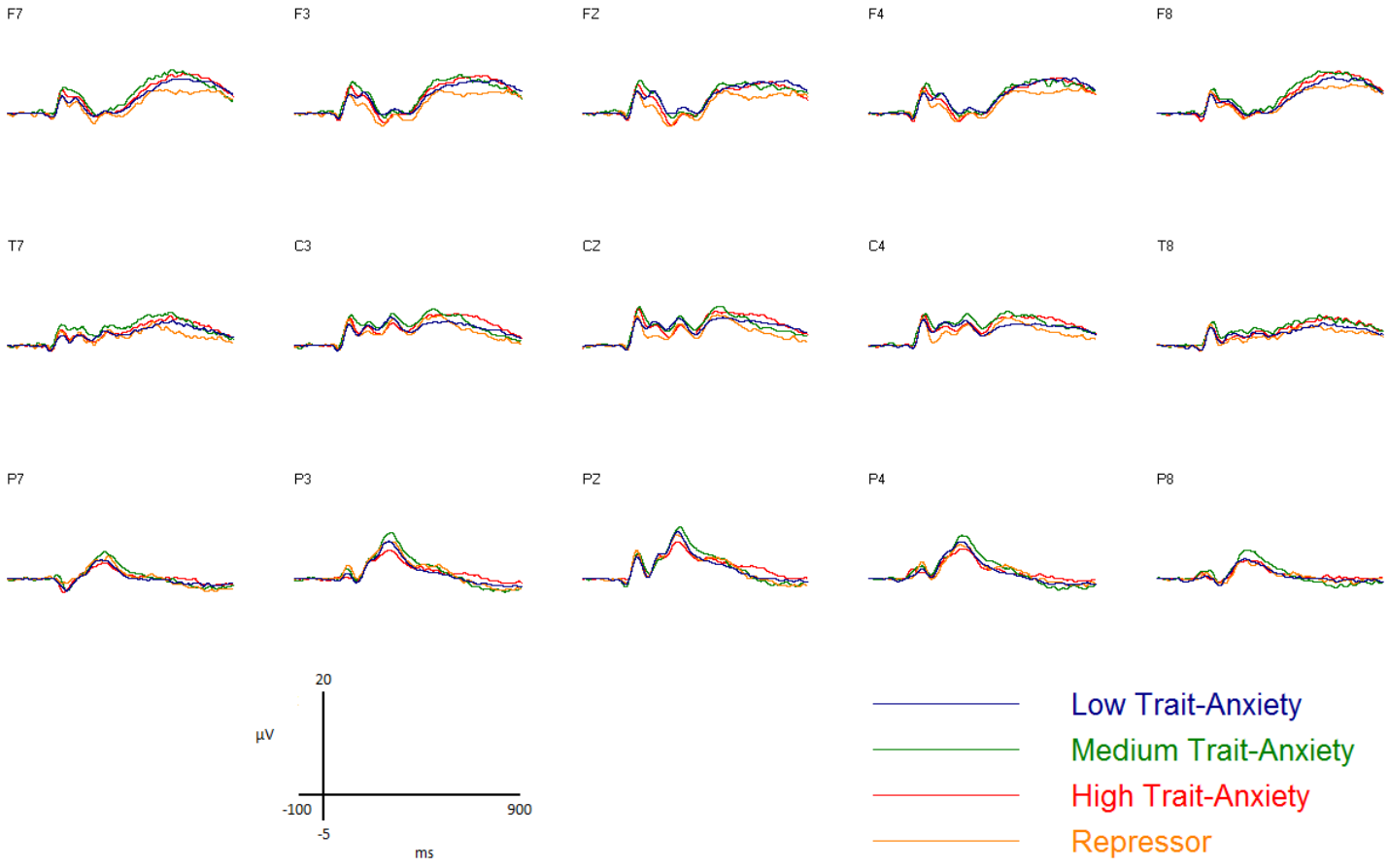
Full array of grand mean waveforms for control trials for each of the four groups (refer Figure 7.2)



Full array of grand mean waveforms for control trials for each of the four groups (refer Figure 7.2).

Appendix G

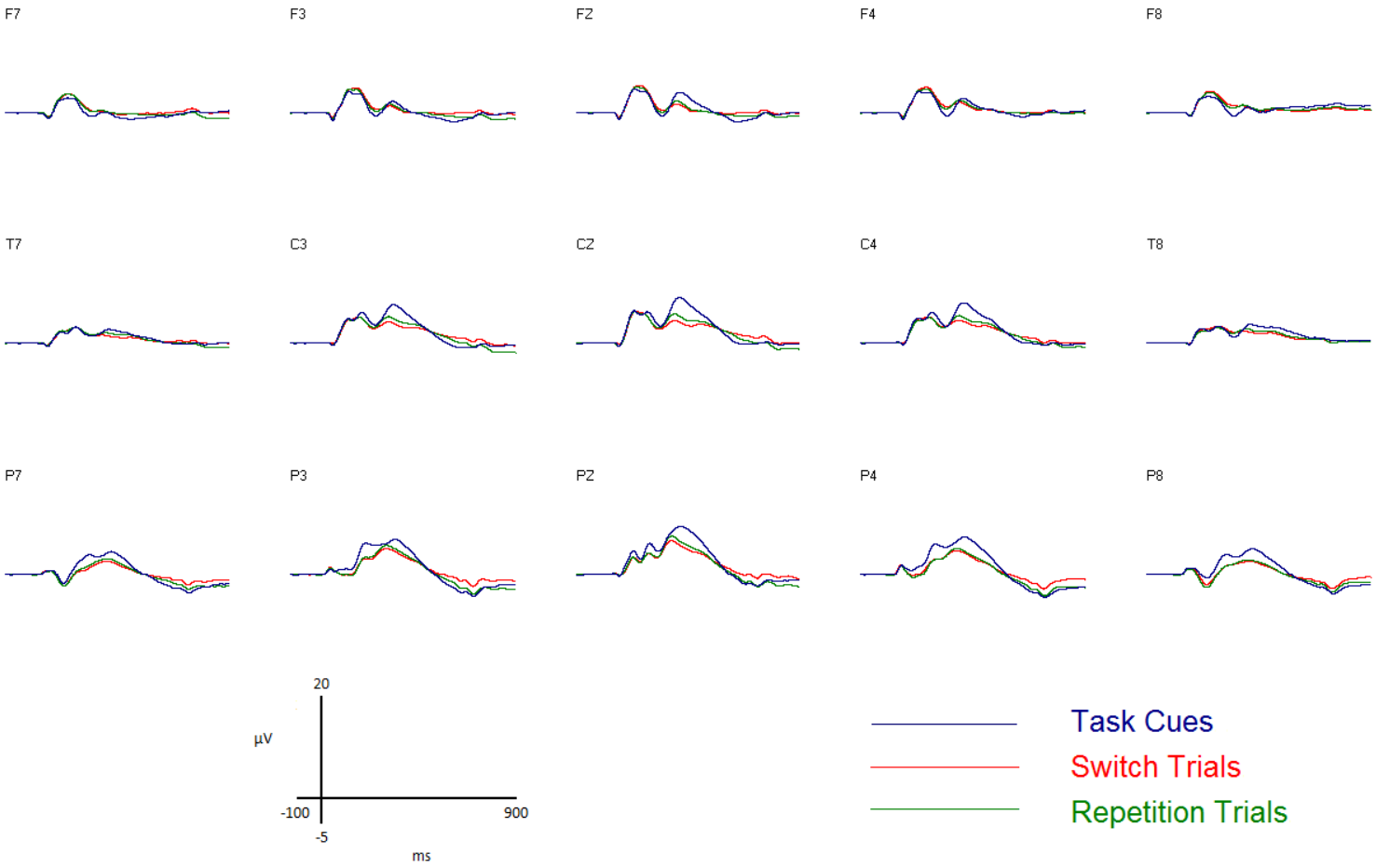
Full array of grand mean waveforms for interference trials for each of the four groups (refer Figure 7.2)



Full array of grand mean waveforms for interference trials for each of the four groups (refer Figure 7.2).

Appendix H

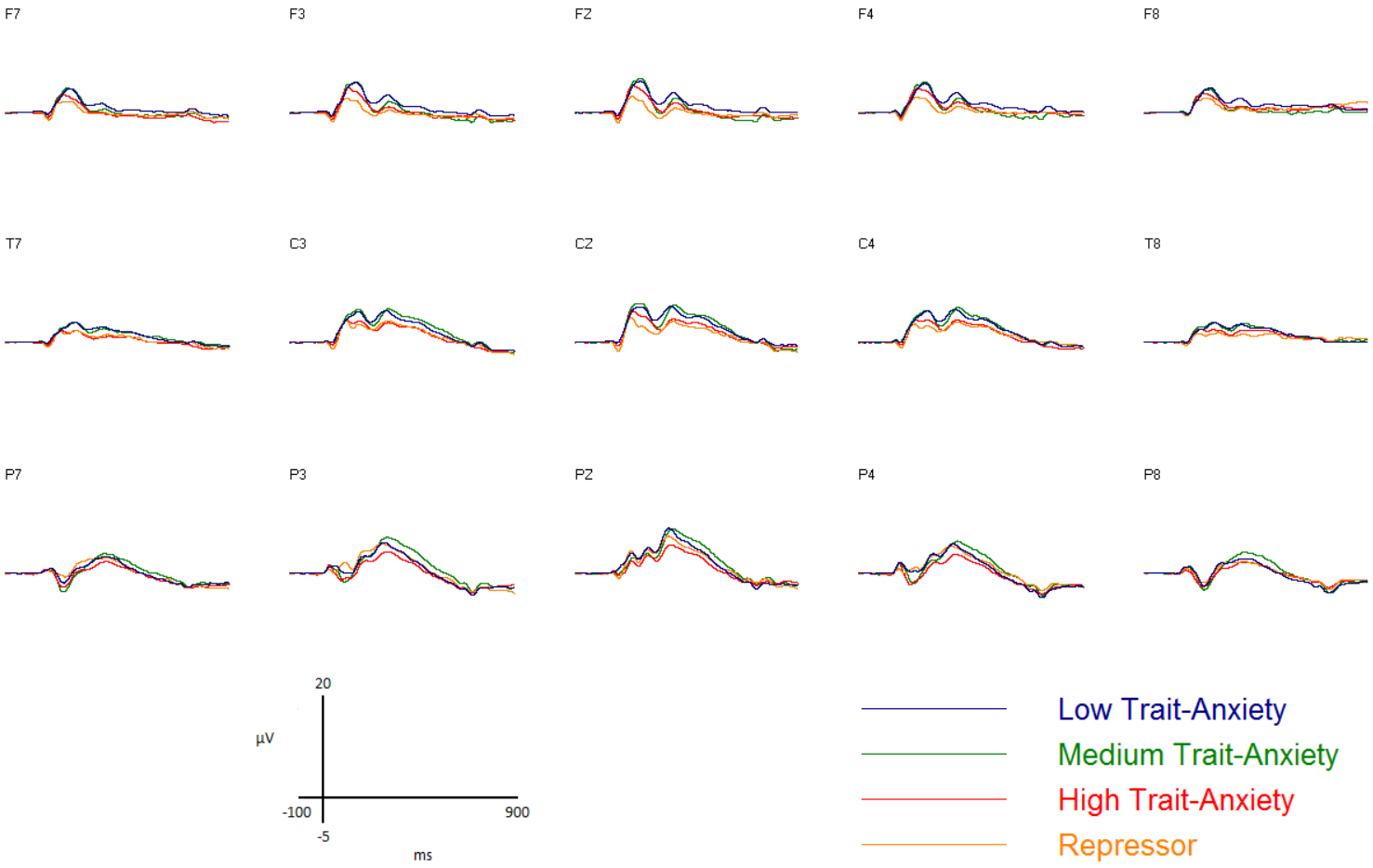
Full array of grand mean waveforms for task-switching cues, switching trials, and repetition trials, collapsed across both, local and global tasks, and each of the four groups, for the task-cueing paradigm (refer Figure 8.5)



Full array of grand mean waveforms for task-switching cues, switching trials, and repetition trials, collapsed across both, local and global tasks, and each of the four groups, for the task-cueing paradigm.

Appendix I

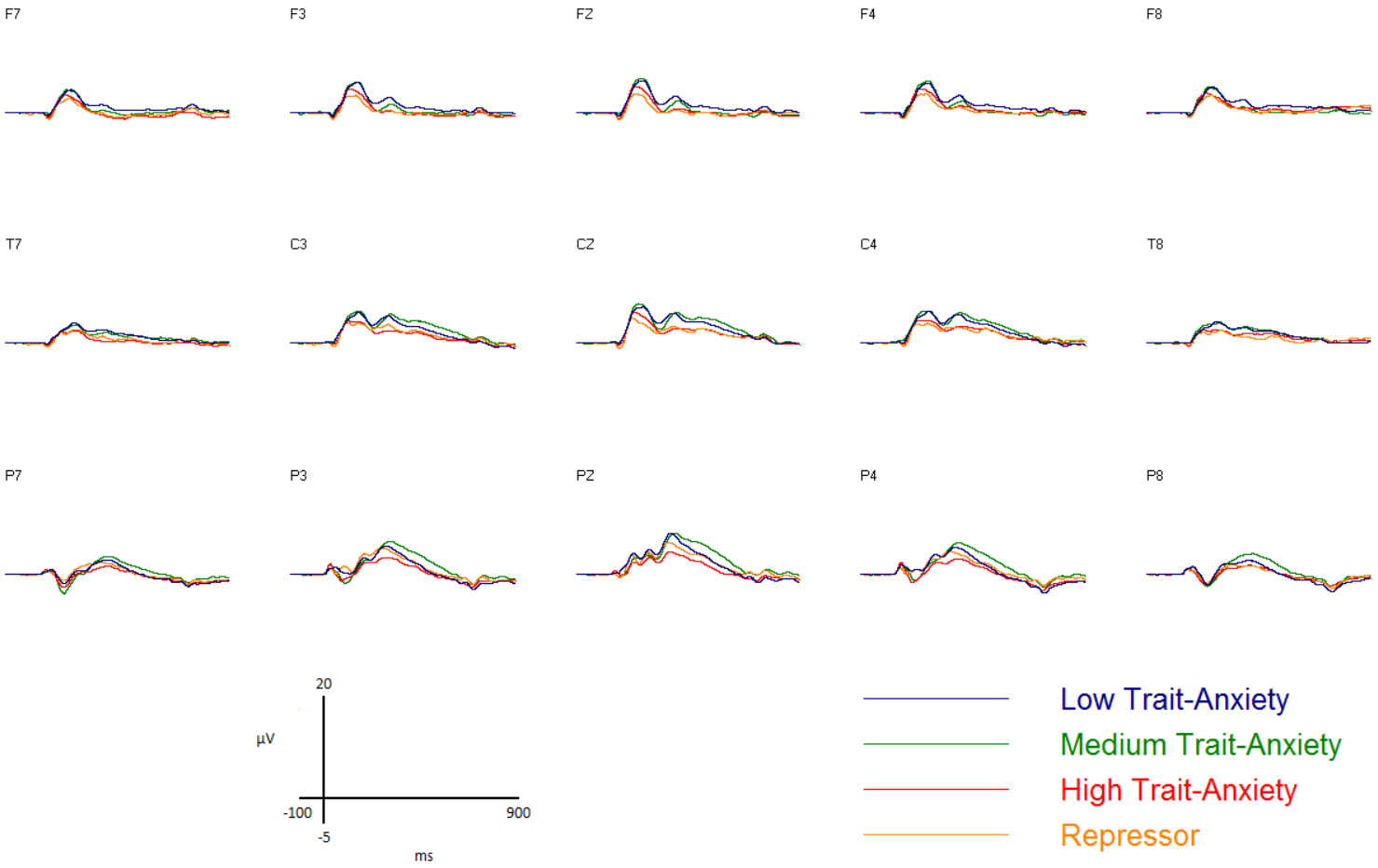
Full array of grand mean waveforms for repetition trials for each of the four groups, across all conditions (refer Figure 8.6)



Full array of grand mean waveforms for repetition trials for each of the four groups, across all conditions.

Appendix J

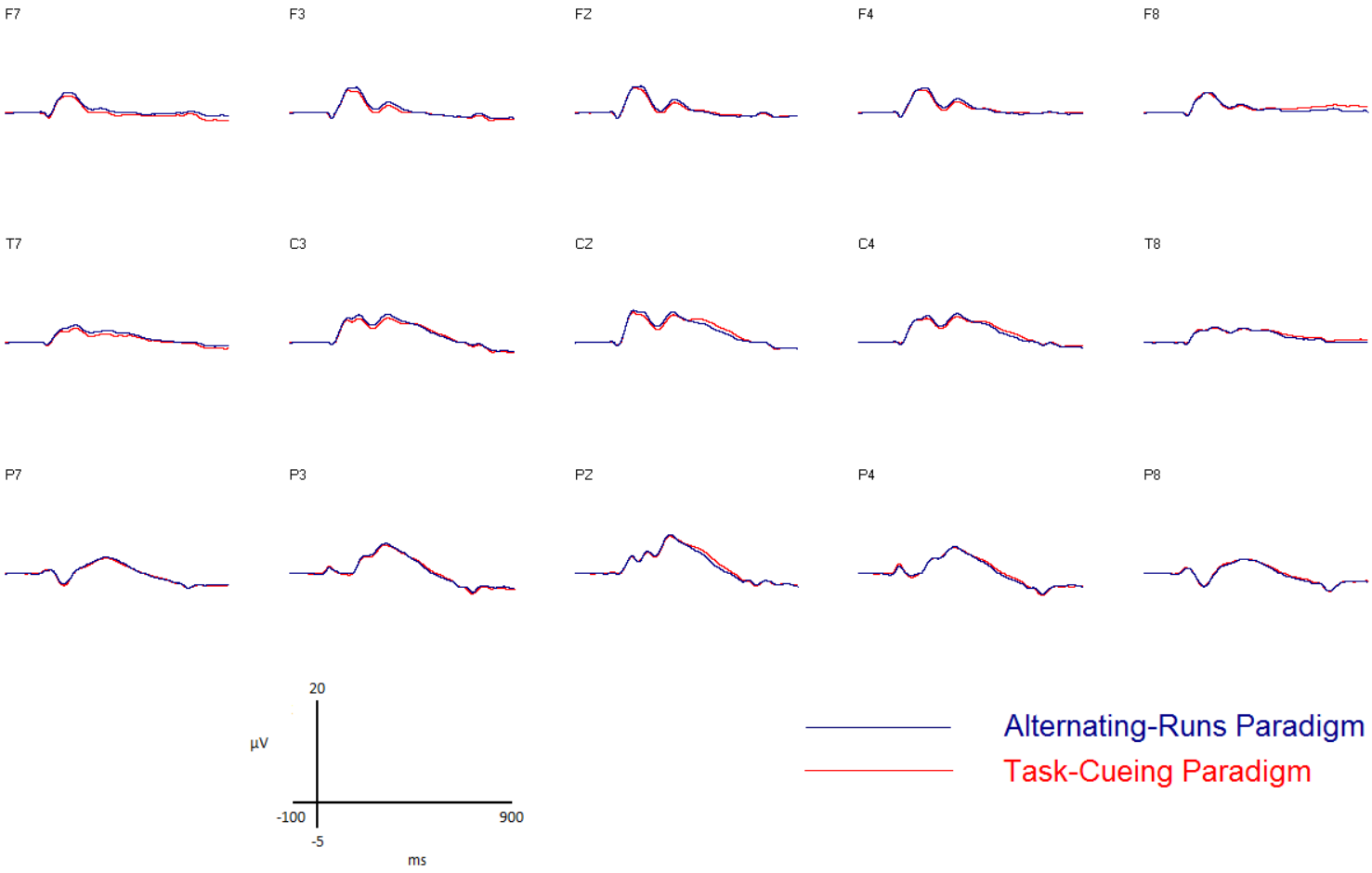
Full array of grand mean waveforms for switch trials for each of the four groups, across all conditions (refer Figure 8.7)



Full array of grand mean waveforms for switch trials for each of the four groups, across all conditions.

Appendix K

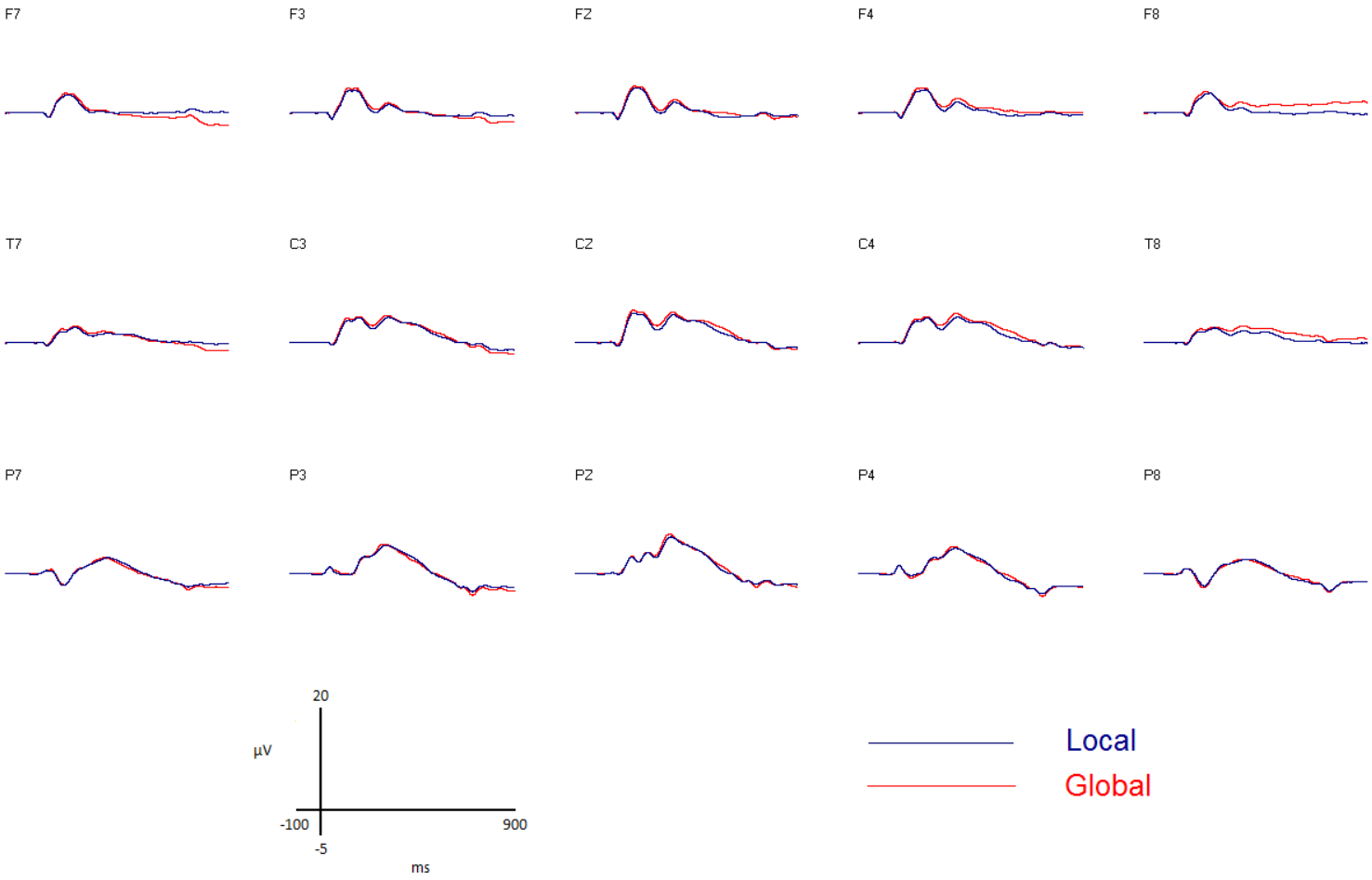
Full array of grand mean waveforms for repeat trials, for both the alternating-runs and task-cueing paradigms (refer Figure 8.7)



Full array of grand mean waveforms for repeat trials, for both the alternating-runs and task-cueing paradigms.

Appendix L

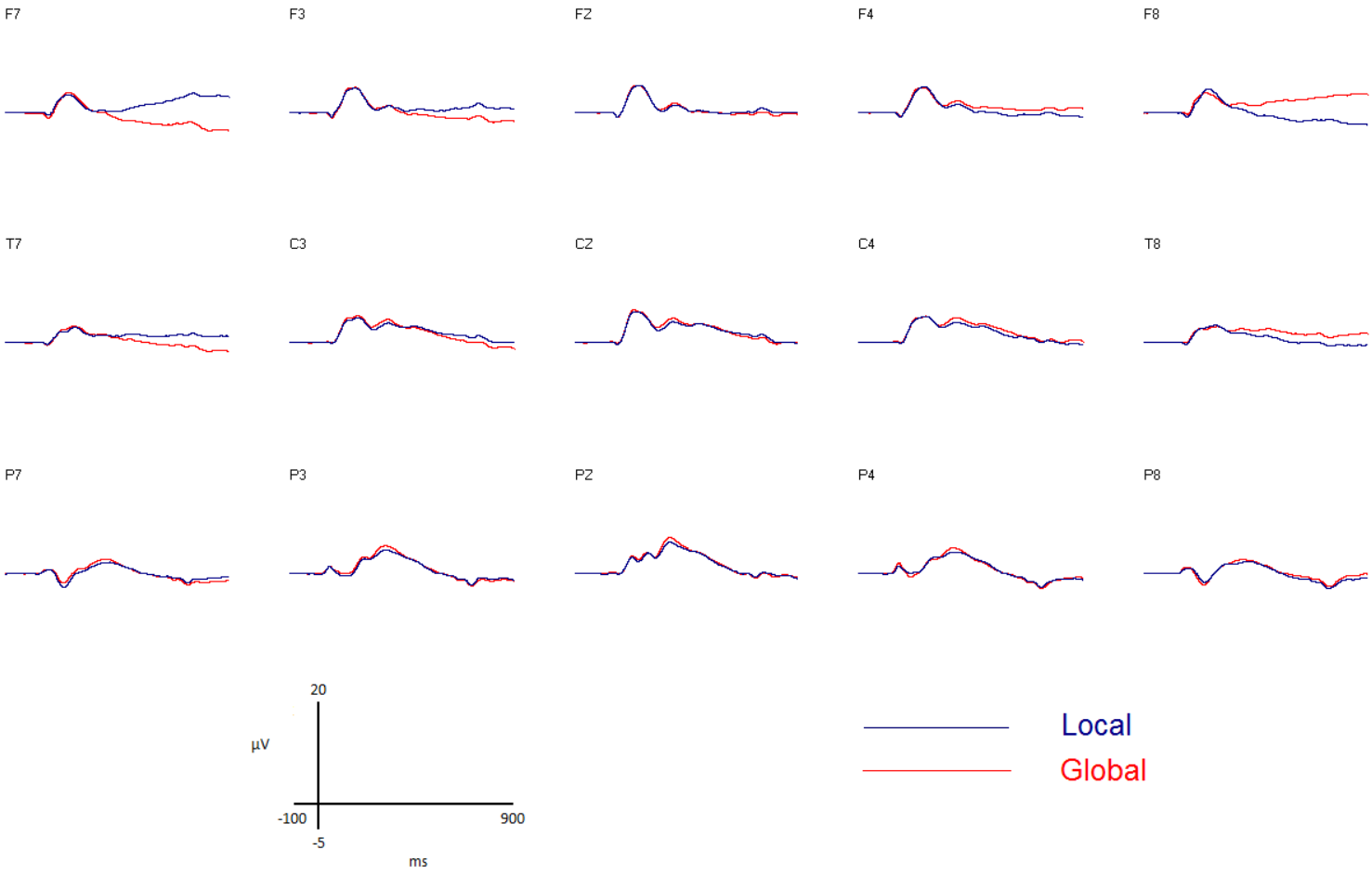
Full array of grand mean waveforms for repetition trials, for both local and global tasks, within the task-cueing paradigm (refer Figure 8.8)



Full array of grand mean waveforms for repetition trials, for both local and global tasks, within the task-cueing paradigm.

Appendix M

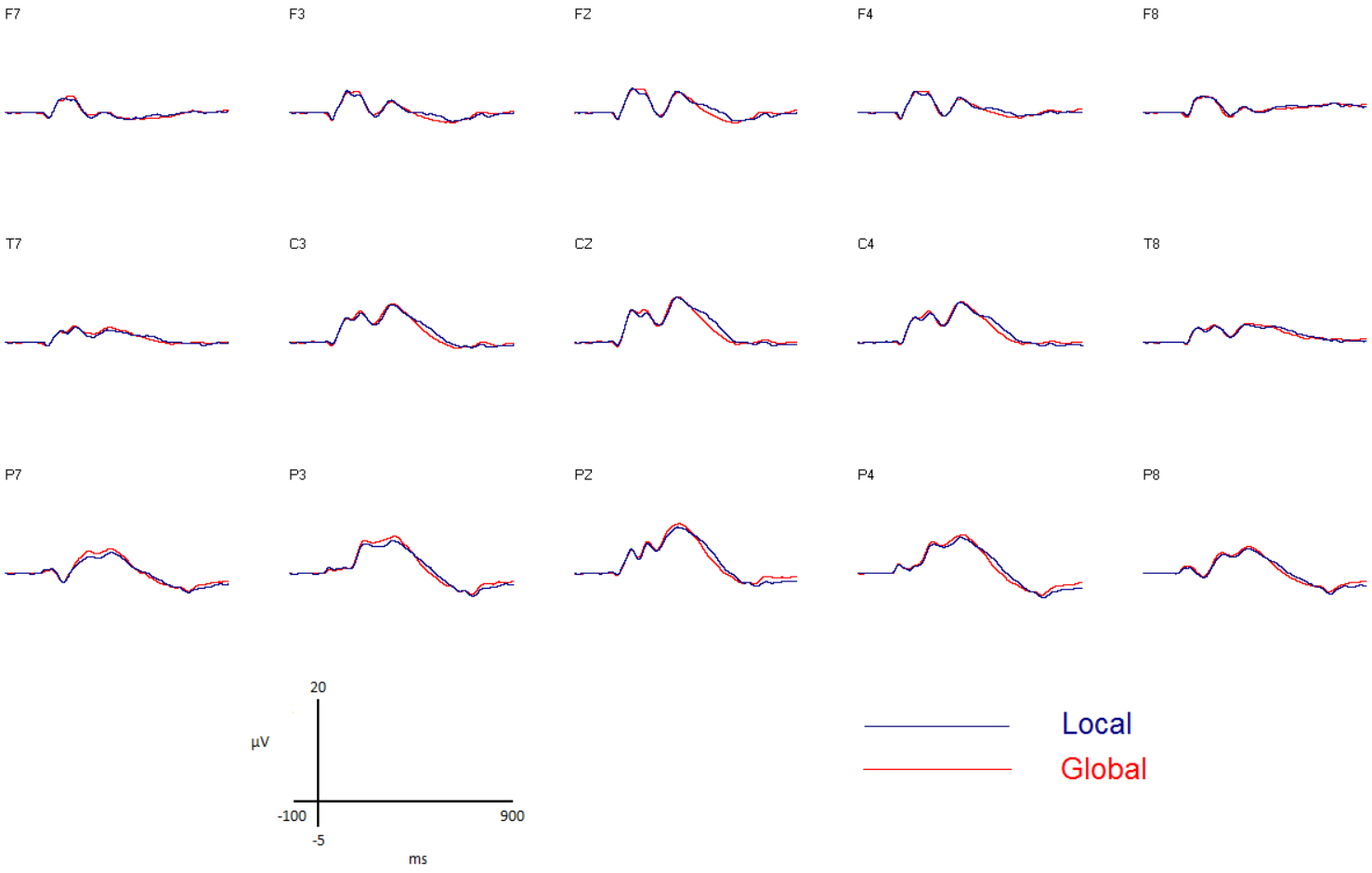
Full array of grand mean waveforms for switch trials, for both local and global tasks, within the task-cueing paradigm (refer Figure 8.8)



Full array of grand mean waveforms for switch trials, for both local and global tasks, within the task-cueing paradigm.

Appendix N

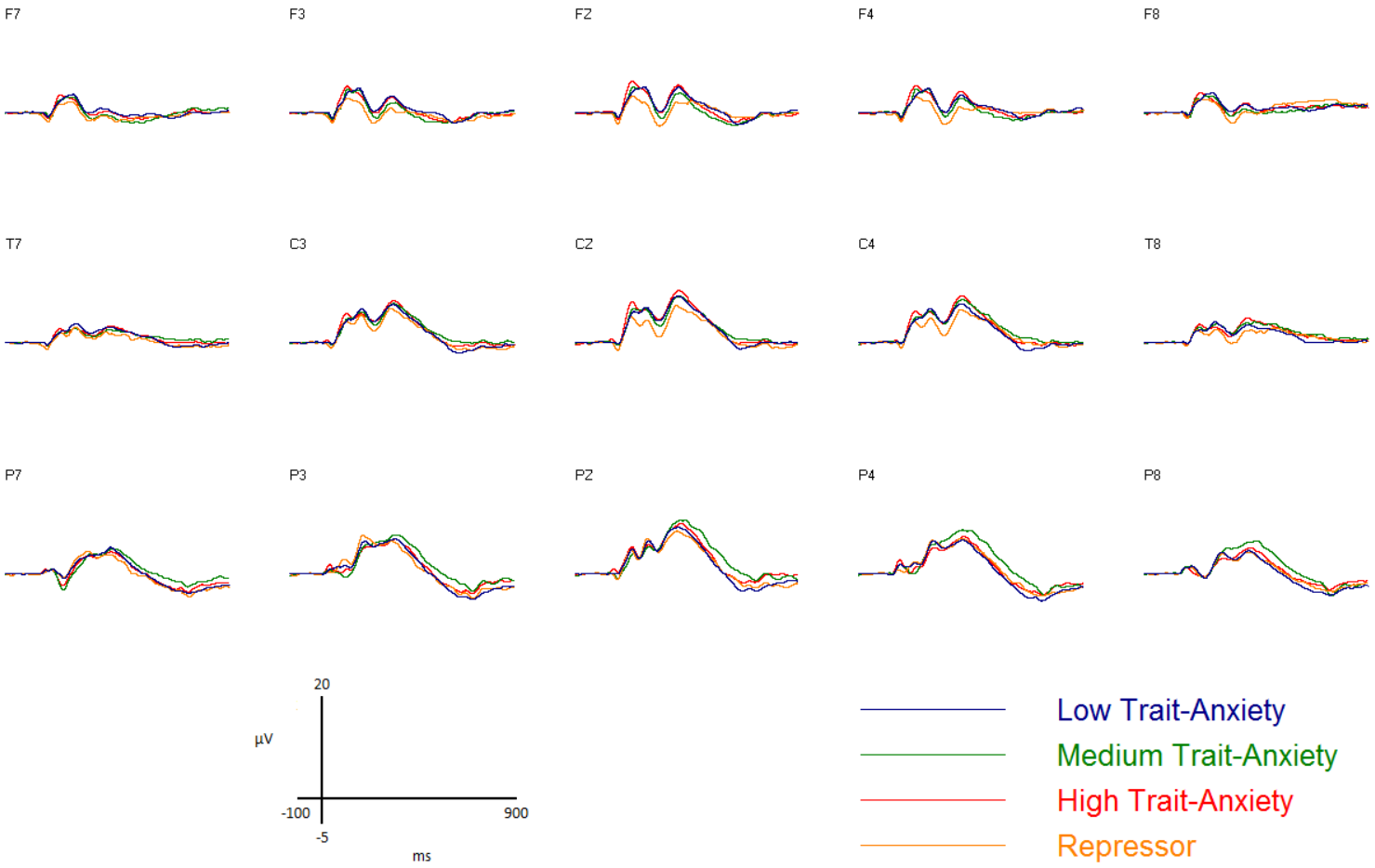
Full array of grand mean waveforms for switch-cues, for both local and global tasks, within the task-cueing paradigm (refer Figure 8.8)



Full array of grand mean waveforms for switch-cues, for both local and global tasks, within the task-cueing paradigm.

Appendix O

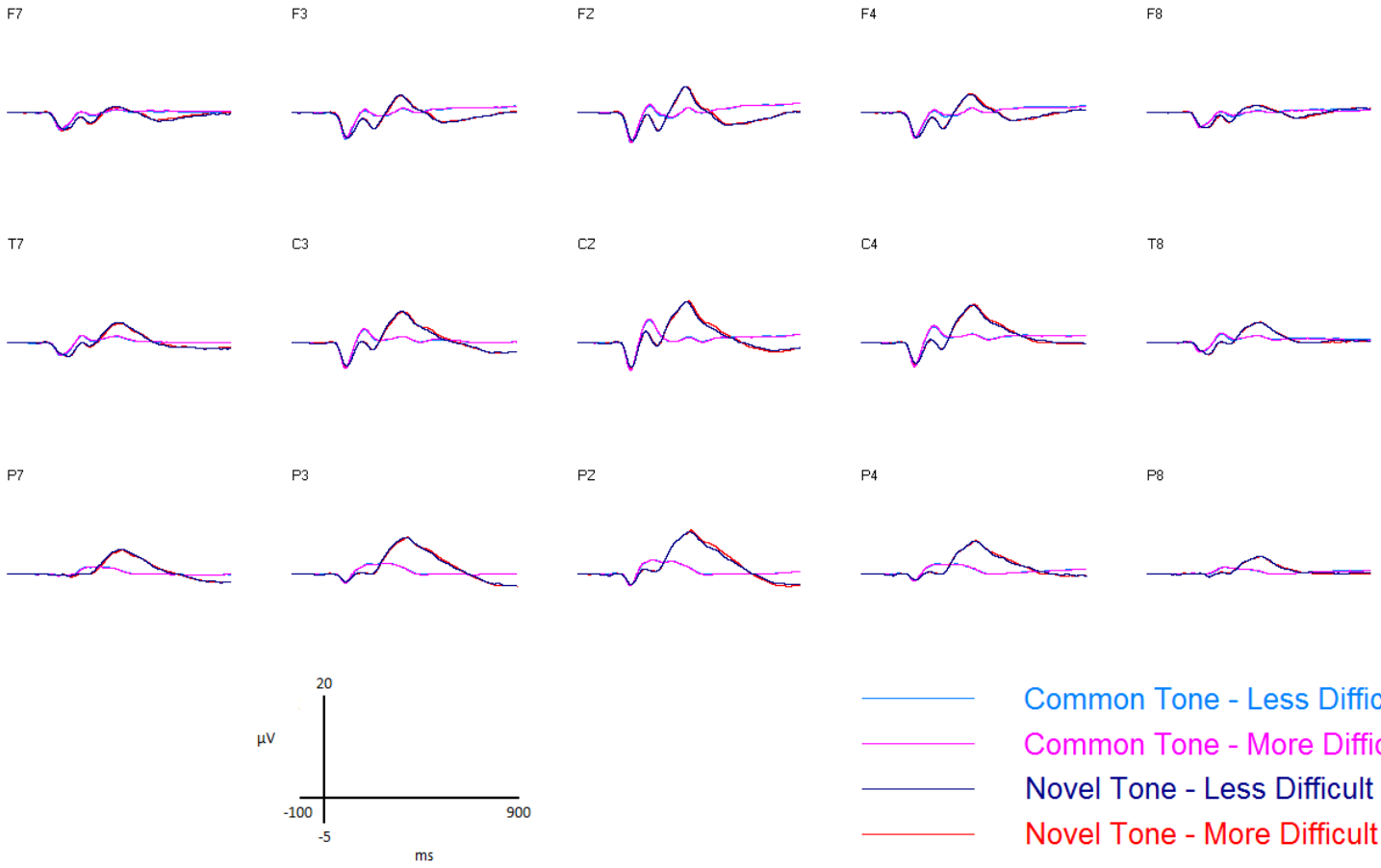
Full array of grand mean waveforms for switch cues, for each of the four groups, across both local and global tasks, within the task-cueing paradigm (refer Figure 8.9)



Full array of grand mean waveforms for switch cues, for each of the four groups, across both local and global tasks, within the task-cueing paradigm.

Appendix P

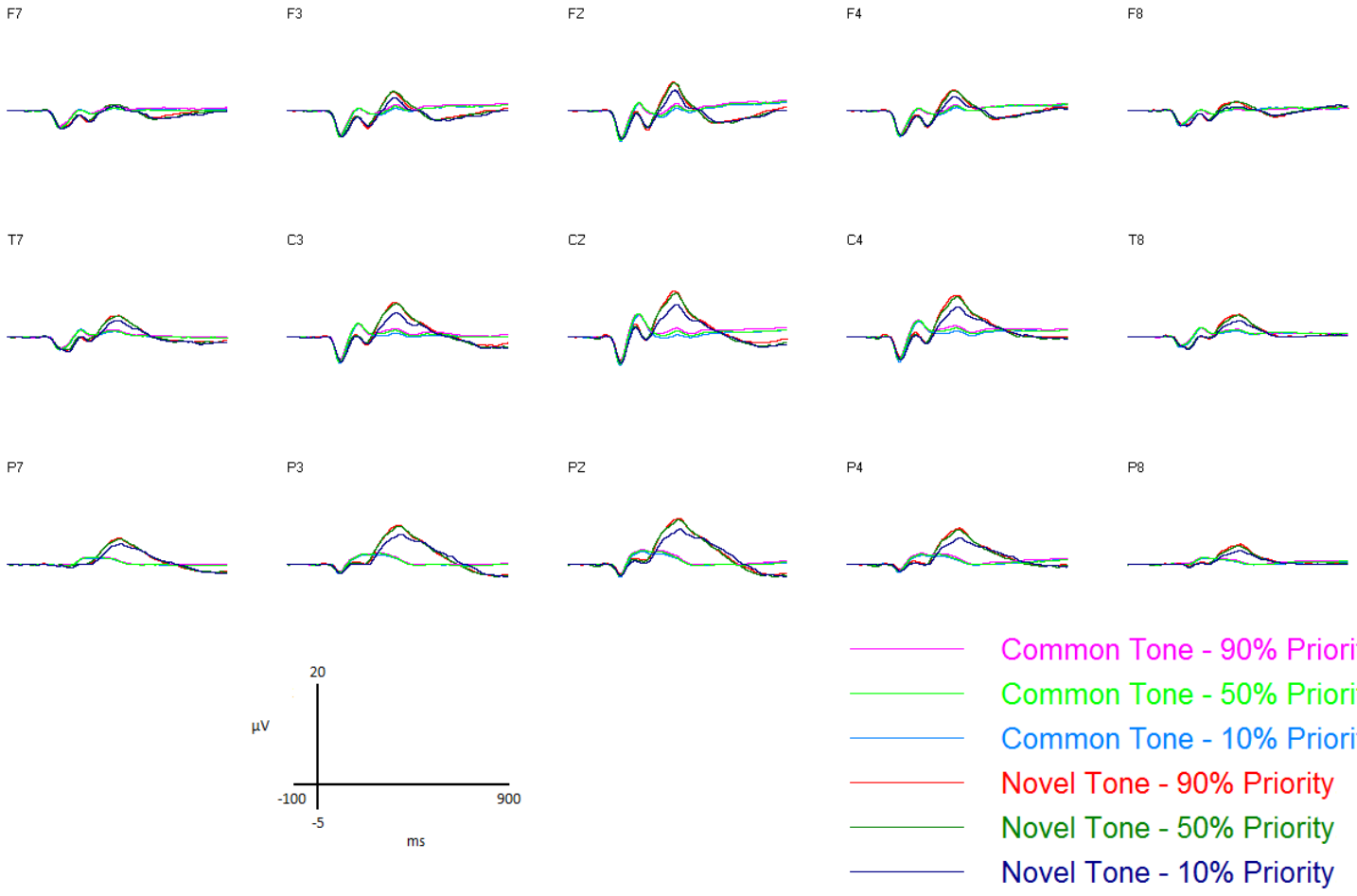
Full array of grand mean waveforms for common and rare tones at both levels of task difficulty (refer Figure 9.3)



Full array of grand mean waveforms for common and rare tones at both levels of task difficulty.

Appendix Q

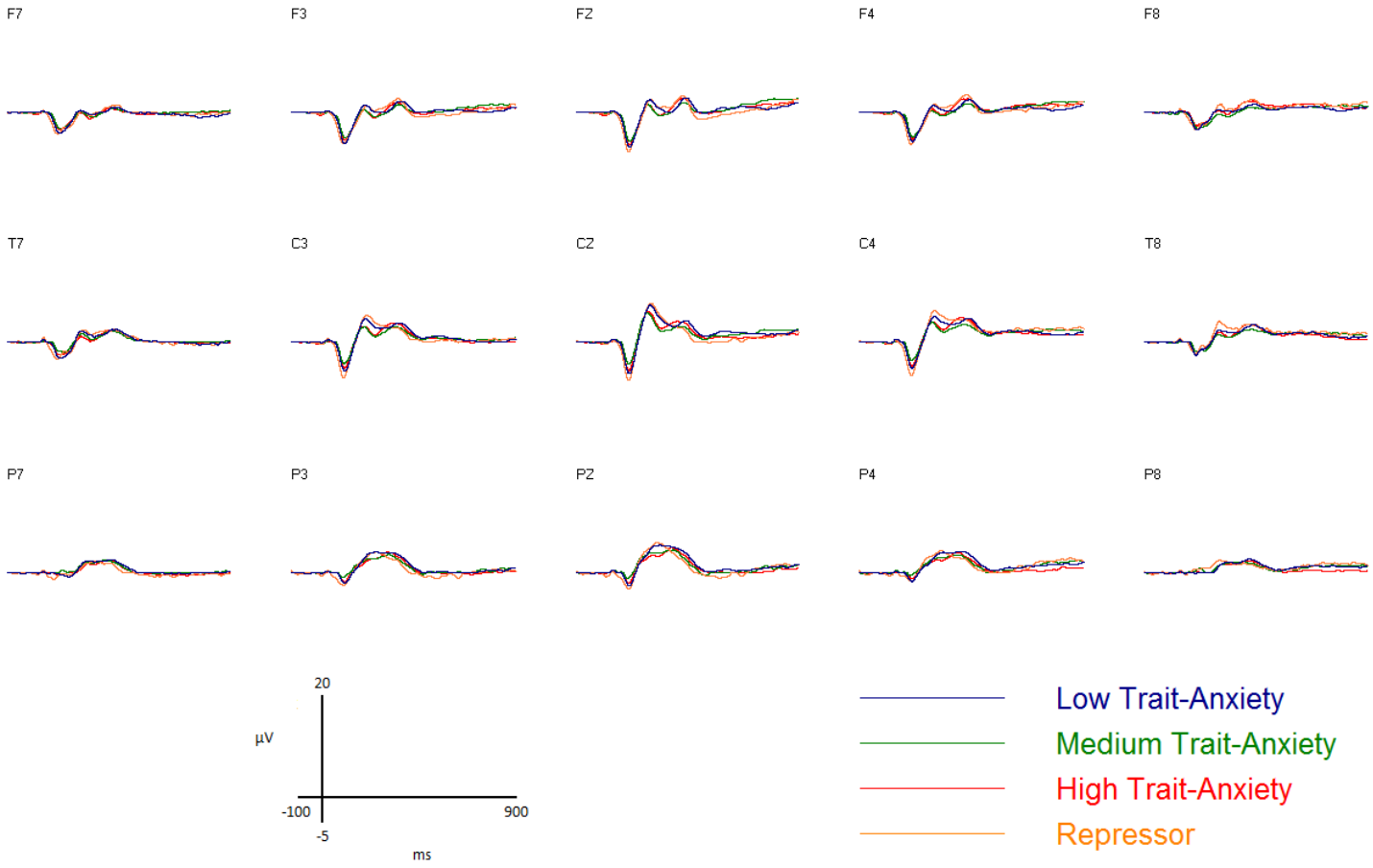
Full array of grand mean waveforms for common and rare tones at each level of priority (refer Figure 9.4)



Full array of grand mean waveforms for common and rare tones at each level of priority.

Appendix R

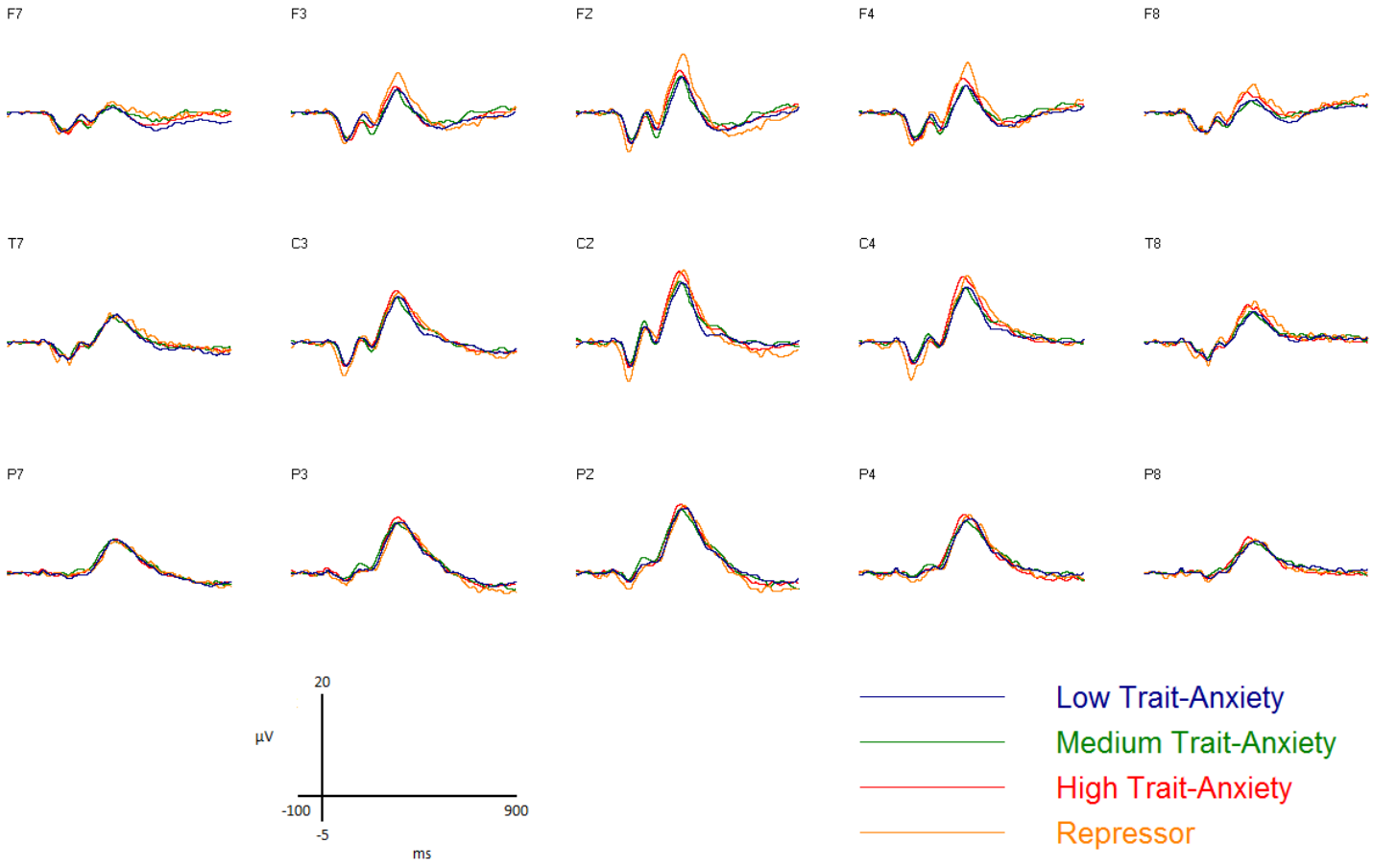
Full array of grand mean waveforms for common tones for each of the four groups (refer Figure 9.5)



Full array of grand mean waveforms for common tones for each of the four groups.

Appendix S

Full array of grand mean waveforms for rare tones for each of the four groups (refer Figure 9.5)



Full array of grand mean waveforms for rare tones for each of the four groups.